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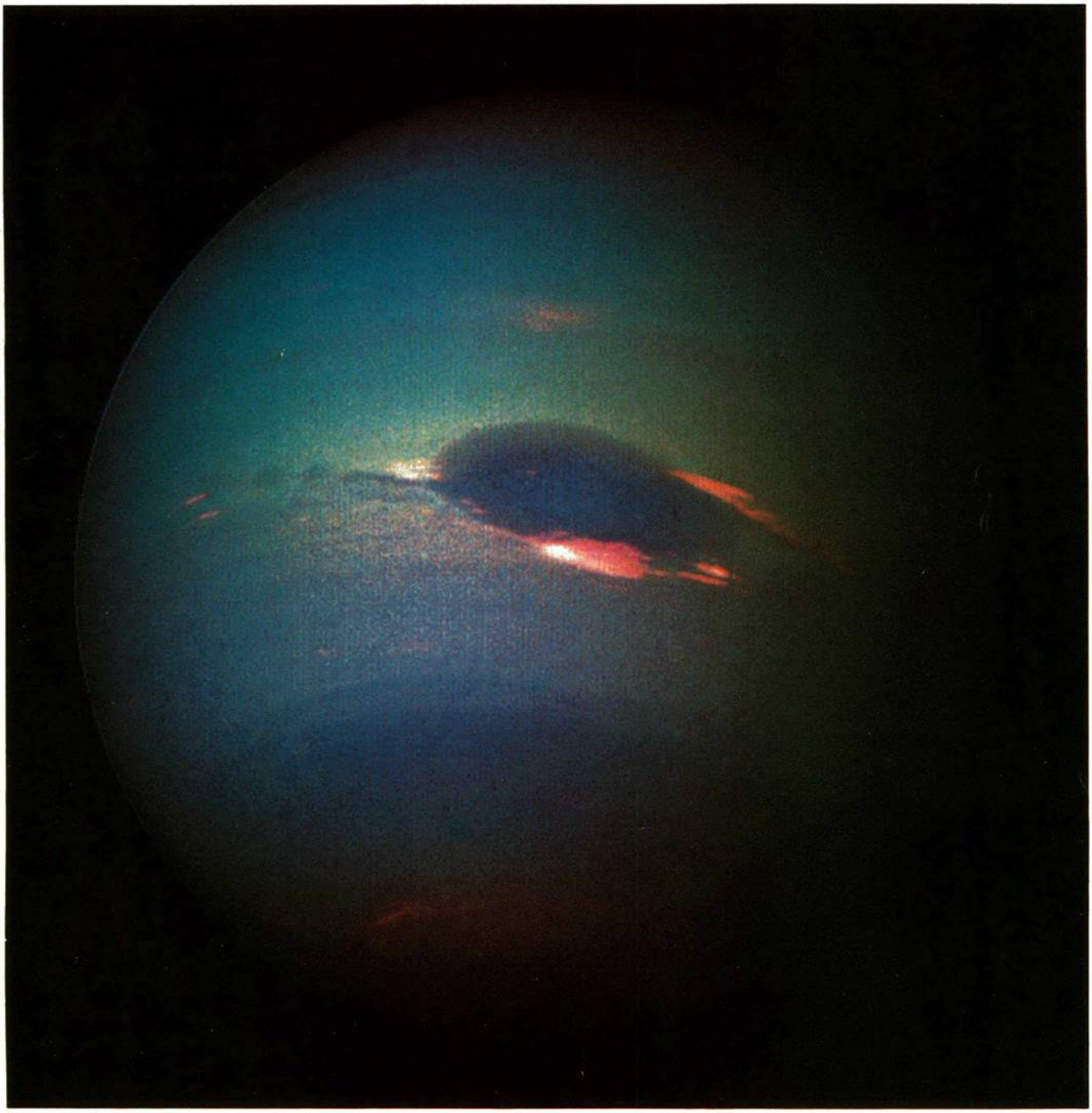

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"My experience with Meade Instruments is consistently on a higher level than with other astronomical equipment manufacturers. One Meade product is so outstanding I must comment on it. **The Meade Series 4000 eyepieces are clearly the finest eyepieces available.** I have owned or used just about every other commercially manufactured Plössl eyepiece, and one does not need to be a seasoned observer to immediately notice the difference."—**Michael Barnett, Westlake Village, Calif.**

"Several hundred amateurs had the chance to test the performance of Meade Series 4000 eyepieces at the Astrofest Telescope Convention. Observing Jupiter with your Ultra Wide 8.8mm on a 7″ f/9 Starfire refractor, the huge 84° field encompassed the entire Jovian system. The four moons were resolved as discs, perfectly round even at the extreme edge of the field. Jupiter itself presented a magnificent show with a multitude of bands, small ovals, and festoons, etched in high contrast on the planet's surface. Meade Ultra Wide Angle eyepieces are a unique design that really bring out the best in a high performance telescope."—**Roland Christen, President, Astro-Physics Corp., Rockford, Ill.**

"Due to annoying field curvature in my Dobsonian telescope, I returned a competitor's 24mm wide-angle eyepiece, and ordered a Meade Series 4000 Super Wide Angle 24.5mm. To my delight the Meade ocular essentially eliminated field curvature while maintaining "Plössl-like" edge to edge sharpness. I now also own the Meade Super Wide 13.8mm that has absolutely the flattest field I have ever encountered in a six-element wide-angle eyepiece. I was skeptical at first of your claims that the Series 4000 are the best eyepieces, but am now a believer."—**Richard D. Clark, Grand Junction, Colo.**

"As a former staff member at Mt. Wilson and Palomar Observatories, I have had access to some of the finest optics, including eyepieces, ever produced. When I performed some critical evaluations of the Meade Series 4000 eyepieces, it was immediately apparent that as a result of these eyepieces, the telescopes used for my tests were operating at a new visual performance level. With regard to such parameters as image contrast, definition, field flatness, and secondary spectrum, without exception these eyepieces achieved the highest level of professional precision. I find it rather difficult to comprehend there being any room for future improvement."—**Paul Roques, Williams, Ariz.**

"I had the opportunity to compare your series 4000 eyepieces with those of the other premium brand. Comparisons were made using DFM Engineering 16″ and 18″ telescopes at the University of Colorado. A wide range of focal lengths were compared, but I found the Meade Series 4000's to be preferable in all cases. The Meade eyepieces had less color, gave better definition, more field of view, and more comfortable eye relief. In addition the Meade Super Wide Angle 40mm provided noticeably more field than did the competing brand's; measurements against a star field verified this fact."—**Dr. Frank Melsheimer, President, DFM Engineering, Inc., Longmont, Colo.**

U.S. and Canada Dealer Locations & Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments toll-free from anywhere in the continental U.S.A. (except Calif.): **1-800-854-7485.** From all other areas, including California, call direct: **(714) 556-2291.**

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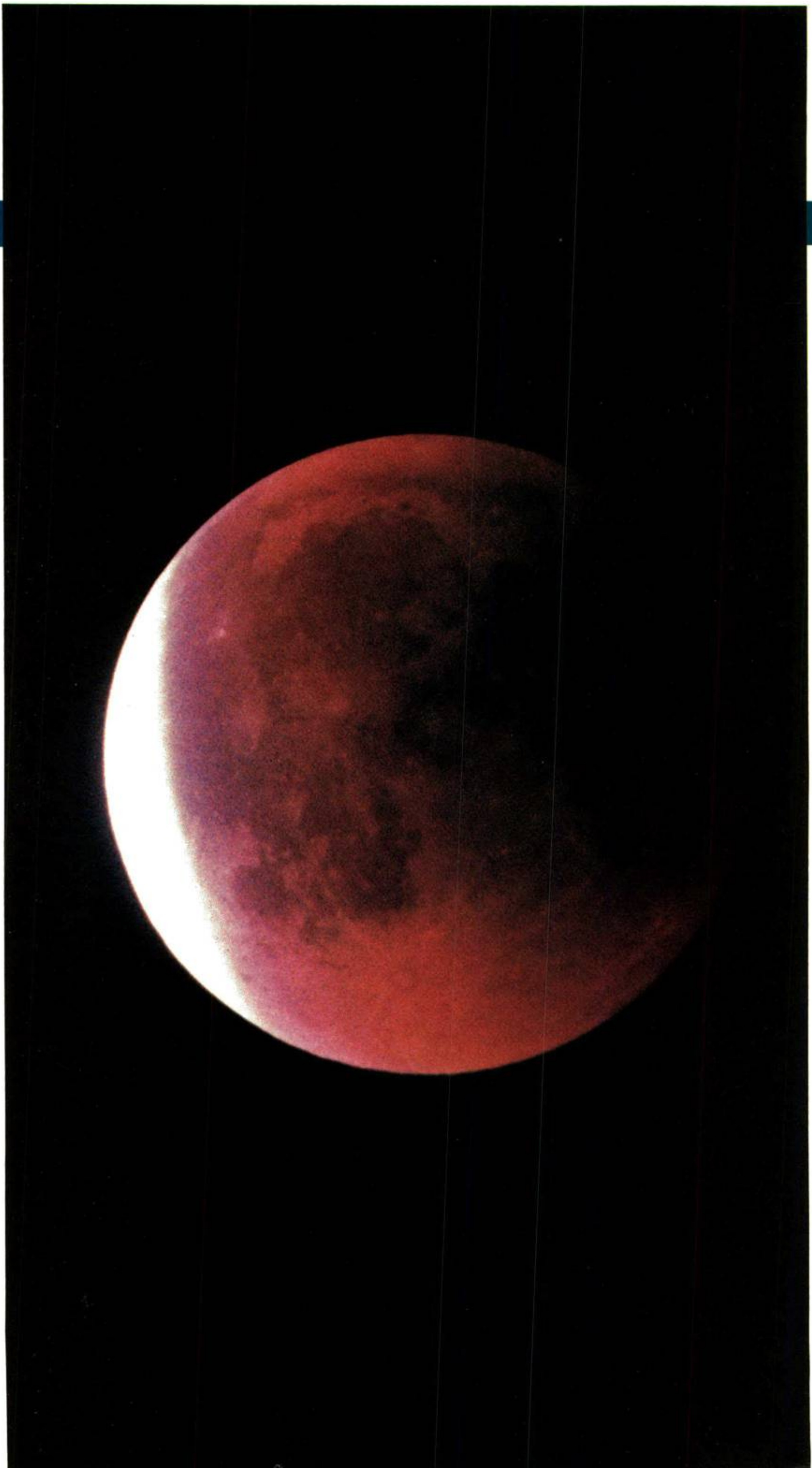
ON THE COVER: Deep clouds in Neptune's atmosphere appear blue, while high clouds show pink or white in this color-enhanced *Voyager* image.



VIOLET, HAZEL, and rust hues stain the Moon's surface during the August 16 total lunar eclipse. Photo by Don Thorson and Mike Racer.

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The Audit Bureau

Behind the Scenes

REVIEWS BREED QUALITY TELESCOPES

"Dear ASTRONOMY, Could you tell me the best telescope to buy?" So begins a typical letter from an ASTRONOMY reader. A year ago we decided that our job as the leading magazine in the field of astronomy includes publishing unbiased, hands-on reviews of the telescopes that are the basis of amateur astronomy. In that year we've learned a few things.

Our experience with small refractors for the review we published in the October issue ("ASTRONOMY Surveys Twelve Small Refractors") surprised us. When we began work on that review, we expected to find some good brands, some poor brands, and some broad patterns in the small refractor market. Instead we found there was little correlation between quality and brand-name. Under their paint jobs, many small refractors seem to be virtually identical. Although we would not condemn a company's entire line based on one bad telescope, our sample indicated to us that some of these companies do little to monitor or control what they sell under their names.

Our goal is an objective report on the features and performance of a significant and recently introduced product of interest to a wide range of readers. For our December issue, we identified the Meade 2120 10-inch f/6.3 Schmidt-Cassegrain telescope as a significant new product. In reviewing it we tell our readers what the telescope offers, how well it's built, how well it functions, and what it's like to use.

A few days ago Mark Coco from Celestron called me. "Richard," he said, "I want you to know that since ASTRONOMY's review in May, we've been hard at work fixing the things you people noted in your review of the Ultima 8." That simple statement was music to my ears. What it means is that the time and work we put into examining that telescope will benefit everyone, and that a very good product from Celestron is on its way to becoming an excellent product.

We are confident that as ASTRONOMY's reviews become established as a way of life in amateur astronomy, everyone will benefit. For our readers we expect better products — and a more enjoyable hobby. Manufacturers can expect better sales because you will buy their products with confidence. When quality improves, everyone wins. As your astronomy magazine, it's our job to make it happen.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Watch Your Step

I have read several letters in ASTRONOMY over the past few years regarding amateur astronomers who have had some misfortune at remote observing sites because they and their equipment looked suspicious to those unfamiliar with the trappings and habits of our hobby. I hope readers take these letters seriously.

During the return of Comet Halley, my friends and I were taking photographs on a deserted road with a camera, tripod, and 210mm zoom lens combination. Apparently, the camera looked menacing, as cameras often will.

We were all quite annoyed when a car pulled into our observing site without dowsing its headlights. I recall heading off into the headlights muttering, "I'll handle this."

As I approached the car with camera in hand, imagine my surprise when I was greeted with the sound of a shotgun shell being loaded into a chamber. It was the county police checking on a suspicious group of people on a quiet, out-of-the-way road. We all emerged unscathed, but with a more careful attitude.

These stories are funny after the fact. However, I never want to read about some tragedy arising out of a simple misunderstanding. Let's be careful out there! *— Timothy G. Knauer, Cedar Rapids, Iowa*

Paltry Purchasing Power

I am an amateur astronomer who would love to own a telescope. Therefore, I read your July 1989 Viewpoint column with great interest. The problem, as Alan Dyer pointed out, is that I have never been in a position to afford $1,000 or more to get something decent. I also refuse to purchase the junk found in department stores. These so-called "telescopes" do more to harm our hobby than help it.

It's hard to explain to a well-meaning spouse why the telescope he or she bought as a gift is a piece of trash and should be returned. I know from experience that a decent telescope in the $200 price range would be a great encouragement to would-be astronomers. *— Jim Penkala, Calistoga, California*

Put Out the Red Light

For some time I have used a flashlight with a red light, but I always felt it was too bright. It is an "astronomer's flashlight," so I thought it must be fine. After reading "Don't Forget the Bug Spray" (August 1989), I realized that my flashlight was much too bright.

I tried to tone it down by putting another layer of red plastic in front of the

DEAR MR. NAGLER:

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis.** Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly $20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis.** Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis'** capability, it does prove we were looking at no dim M-31. There was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "...but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!...How am I ever going to make my wife see the need?". One observer even yelled to a friend acoss the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

In case you could have possibly missed my point: I am totally enthralled with my new **Genesis.** Mr. Nagler, what you have created with your **Renaissance** and **Genesis** telescopes has filled a void, beyond binoculars and yet still permitting the beauty of deep sky objects to be viewed 'in context' without resorting to the usual solution of over-magnification that reveals detail at the expense of sacrificing perspective. ■

Because our dark sky observing location attracts late-night dewing and humidity, I appreciate your design consideration of including the fluorite element as a totally internal component, inaccessible to dew, condensation or scratches. ■

It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,

Kent E. Ledlow

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bulb; the change was negligible. I finally came up with two good techniques to dim the light. The first is to put a plain white paper cut-out in front of the bulb. The other is to cut out a circle from a plastic milk carton. This semiclear plastic cut-out dims the light about half as much as the paper cut-out.

I wish I had done this a long time ago. Thanks for jogging me into action. — *Dave Grimmer, Wichita, Kansas*

We Must Have a Place in Space

I do not believe that "Do We Have a Place in Space?" by Harry Shipman (September 1989) accurately reflects the views of space enthusiasts like myself.

In general, space enthusiasts do not believe that human settlement of space is inevitable. Rather, due to our planet's limited resources and burgeoning population, space settlement is a necessity. I challenge Mr. Shipman to devise a long-term, optimistic view of the future that does not embrace space settlement.

In my understanding, the only real impediment to space development can be summed up in two words: launch costs. Two exciting developments, the National Aerospace Plane and Senator Packard's Launch Services Purchase Act, may reduce the costs so that space commercialization will someday be economical. — *Shawn McCaslin, Cedar Creek, Texas*

Some Say Tomato . . .

I've often wondered how words such as "nebulae" and "novae" are pronounced. I've run across them in my reading, but I've never actually heard them spoken. Is the correct pronunciation "nebulee," "nebulie," "nebulay," or something completely different? — *Steve Sutton, Springfield, Georgia*

— The question of the proper pronunciation of Latin words is a matter of conjecture because Latin is no longer a spoken language. The stress of a word can usually be determined fairly easily from the way that the word is used in poetry.

"Nebulay" is seldom used among amateur astronomers; "nebulee" is far more common. On the other hand, "nebulie" is closer to the orthodox pronunciation taught in schools. Take your pick.

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity. ☐

Viewpoint

WE CAN OUTLIVE OUR STAR

by Eugene F. Mallove
and Gregory L. Matloff
Authors of The Starflight Handbook, A Pioneer's Guide to Interstellar Travel *(John Wiley & Sons, 1989)*

Interstellar travel is real, despite what the doubters say. Not only are the first emissaries to the stars already under way (*Pioneers 10* and *11* and *Voyagers 1* and *2*), but many thinkers have devoted considerable attention to finding ways to make trips to the stars by craft much fleeter than these early "slow boats."

Some plans are extraordinarily far-reaching, like the British Interplanetary Society's Daedalus study that envisioned a thermonuclear pulse rocket with scientific instruments that could reach nearby Barnard's star in about half a century. Others, such as the Jet Propulsion Laboratory's study of an interstellar precursor mission, would explore the interstellar medium to a range less than 1 percent of the distance to the nearest star.

To sift the sands of remote worlds is the legitimate goal of interstellar travel.

But to be frank, interstellar travel is not easy. It cannot be accomplished simply by wishing for a convenient wormhole in space-time to drop through to the other side of the universe or for a short hop to a nearby sun.

Why would we want to go to the stars in the first place? Is it not enough to be near the one that lights up our days? Surely, we can study the Sun, study the solar system's planets, moons, asteroids, and comets. But some time soon in cosmic history we will have examined the tiny piece of galactic real estate that is the solar system and it will be time to move on. We will probably want to begin starflight in earnest even before the solar system has been completely explored *just because the stars are there.*

What draws us to the stars are not those fusion fires themselves but the planets that attend many if not most suns — at least 50 percent by some recent informed estimates. But to sift the sands of these truly remote worlds, to explore those planets and moons for the first glimmerings of life or the remains of extinct life, to sense the beauty of their environments through the dispatch of robot instruments or from the reports returned by human crews — these are our dreams and the legitimate goals of interstellar travel.

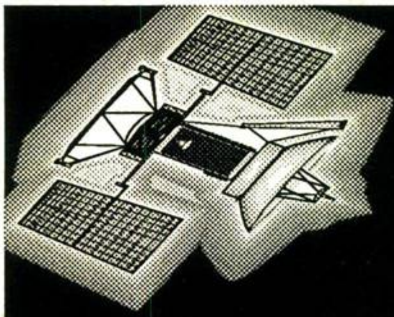
There are many, however, who suggest that exploration or colonization by humans of extrasolar planets will never be done because there is a way to accomplish this for "free." We can simply cock our radio telescope ears to the heavens, search patiently for signals from other civilizations, and tune into a galactic network of interstellar information. The sensible and noble idea of "conventional" SETI — the search for extraterrestrial intelligence — has great promise and deserves fervent support.

But it is by no means certain that such interstellar signaling will be a prevailing mode of galactic discourse, even though we would like to believe that it is. One can imagine, for example, a civilization of dolphinlike ocean creatures among whom are philosophers, mathematicians, poets, and musicians, but who have not had the means to develop technology.

On the other hand, compelling scientific reasons may arise within the next fifty years to encourage serious thought about robotic probes to nearby solar systems. Advanced techniques in optical astronomy may make possible not only the detection of Earth-size planets orbiting nearby stars, but also the determination by spectroscopy of the hallmarks of living extrasolar worlds. If the examination of the radio spectrum of these worlds by SETI researchers revealed no evidence of technological civilizations, starflight would be the only way to investigate them in detail.

Starflight is much more than a hedge against the failure of SETI efforts. Starflight is indeed the ultimate means by which terrestrial life and human culture can stabilize itself against local astrophysical or even provincial biological catastrophes. The interstellar imperative — the "bottom line" of starflight — is that ours should become a civilization that can outlive its star.

About five billion years from now, the Sun will expand into an angry red giant, incinerating all the creations of humanity that might still exist in the inner solar system. Some people say, "Why concern ourselves about the distant future?" We say *stardust* to that! It is never too soon to start thinking about interstellar expansion for the long-term preservation of terrestrial life. The time is now! ☐



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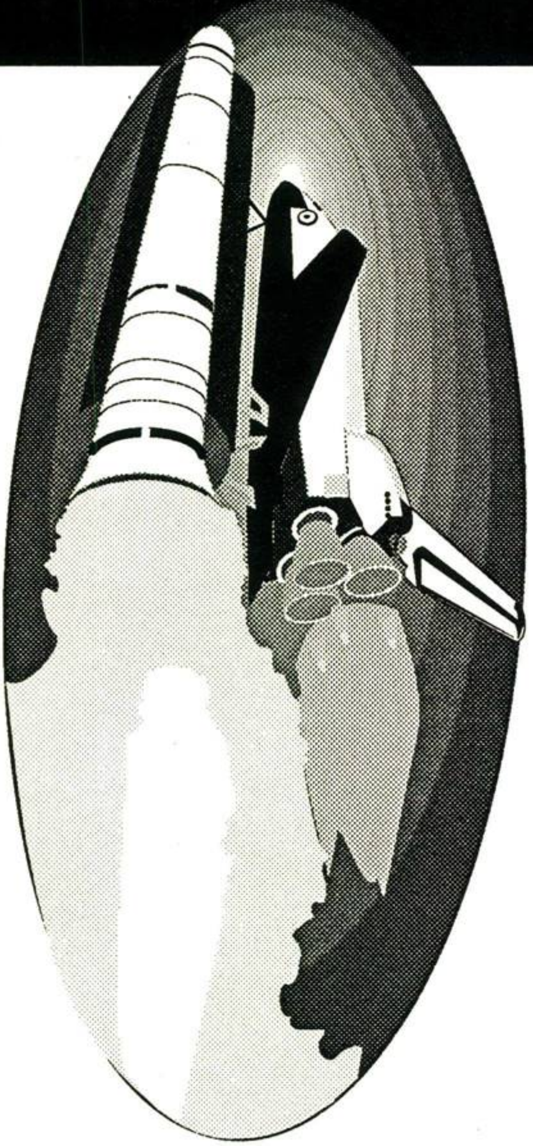

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ISLAND GAS CLOUD MAY BE PROTOGALAXY

When two astronomers aimed the 305-meter Arecibo radio telescope in Puerto Rico at a blank piece of sky last summer, they serendipitously discovered something that may throw a monkey wrench into established theories of galaxy formation: a nearby protogalaxy.

The discovery began unfolding last spring when Riccardo Giovanelli, head of the Arecibo Radio Astronomy Group, and Martha P. Haynes of Cornell University aimed the feed antennas of the Arecibo telescope toward a blank region of the sky in Virgo to calibrate the instrument, which is a precautionary step to minimize measurement errors. But instead of blank sky, their receiver registered a radio signal where no radio or optical object was mapped. As the summer progressed, the signal did not fade, and after confirming that it was not manmade interference, Giovanelli and Haynes realized that they had discovered something unusual.

Upon mapping the source, the object emerged as a roughly elliptical cloud consisting of a diffuse envelope surrounding two large clumps of gas. The whole cloud is rotating so slowly that it may have only completed a single rotation since the universe began. The cloud's diameter is over six times larger than our Galaxy but has only one-tenth its mass, or about 21 billion solar masses. Its distance is 65 million light-years.

The object's location, in epoch 2000.0 coordinates, is right ascension 12 hours 27.3 minutes, declination +1° 29 minutes, or about 4 degrees northwest of Gamma (γ) Virginis. If you could see this object, its apparent diameter would be a little over 30 arcminutes, i.e., bigger than the Full Moon.

A careful search of the region using existing optical surveys did not turn up a visible counterpart. Visible light emission would mean that part of the cloud had collapsed into stars. The fact that stars are not apparent, along with the cloud's distance, immensity, and shape, strongly suggests that it is a protogalaxy — a galaxy in the early stages of forming. The study of such an object would help astronomers better understand the stages of galactic evolution, how galaxies form and mature, and where active galaxies and quasars fit into the greater scheme of things.

Although astronomers have long searched for embryonic galaxies, several surveys failed to find any. Their elusiveness, in fact, suggested to many astronomers that these objects don't exist. Hence, the predominant galaxy-formation theory that has emerged over the years asserts that all galaxies formed at about the same time, 1 billion or 2 billion years after the Big Bang. This discovery, however, indicates that galaxies may still be forming.

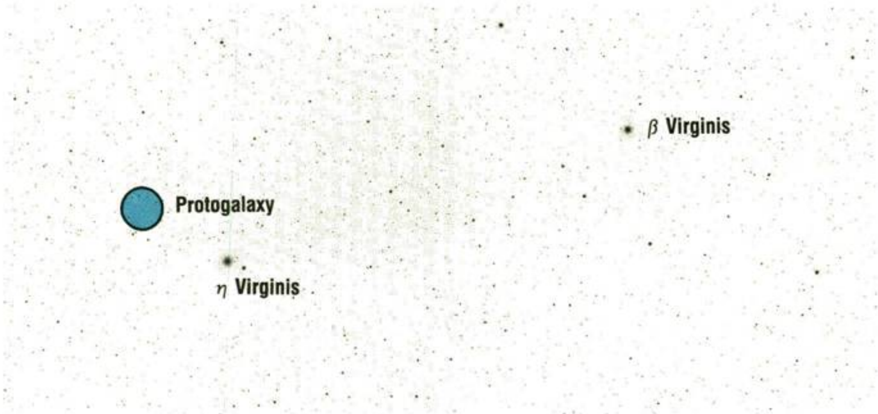
"Before stumbling into this thing, neither I nor Martha were great believers in the existence of such objects," said Giovanelli. "But this cloud indicates that the disks of galaxies can form slowly throughout the history of the universe and not just be something that happened during some magic period in the distant past."

Another significant factor, said Haynes, is that the cloud is isolated in space; the nearest galaxy is several million light-years away. Other extended objects that have been discovered are always closely associated with existing galaxies. But according to Haynes, this cloud seems to have formed independently and has somehow avoided being disturbed by other galaxies.

"We might hypothesize that other clouds like this wouldn't be likely to survive if they interacted with a normal galaxy because the gas in the cloud is very thermally fragile, and if you have any kind of tidal interaction, you would expect it to disrupt. This cloud was just lucky enough not to interact with another object in the last 10 billion years."

The cloud's proximity to Earth will make further studies easier. For example, astronomers can use charge-coupled devices to scrutinize clumps within the cloud for traces of starlight. Infrared observations may also reveal young, smoldering stars or dust. Haynes said they also want to try to see if there are any background objects shining through the cloud, such as a quasar. The light absorbed by the gas in the cloud can be used as a probe to study the cloud's chemical composition.

"What makes it so nice is that now we have something in our backyard that we can study," said Haynes. "If we can understand something about this one, then maybe we can infer what we're seeing in quasars."



THE PROTOGALAXY'S LOCATION is about one and a half degrees northeast of Eta (η) Virginis. If it were visible, it would occupy slightly over half a degree of sky.

KECK STEEL AND MIRRORS SHIPPED TO HAWAII

The structural steel framework for the 10-meter Keck telescope (see "The Telescope That Defies Gravity" by Richard Berry, July 1988) is being assembled this winter at the Keck Observatory atop Hawaii's Mauna Kea, an extinct 13,800-foot volcano that ranks among the finest observatory sites in the world. The 270-ton steel structure was fabricated in Tarragona, Spain, and transported to Hawaii by ship.

The assembly and installation of the telescope framework in the observatory dome should take roughly five months and is scheduled for completion in spring 1990. When it is completed, the telescope structure will stand 80 feet high. Following tests of the bearings, drives, and control systems that point the telescope, engineers will install the first six mirror segments.

These mirrors, which comprise the innermost ring of mirrors in the Keck telescope's hexagonal array of thirty-six mir-

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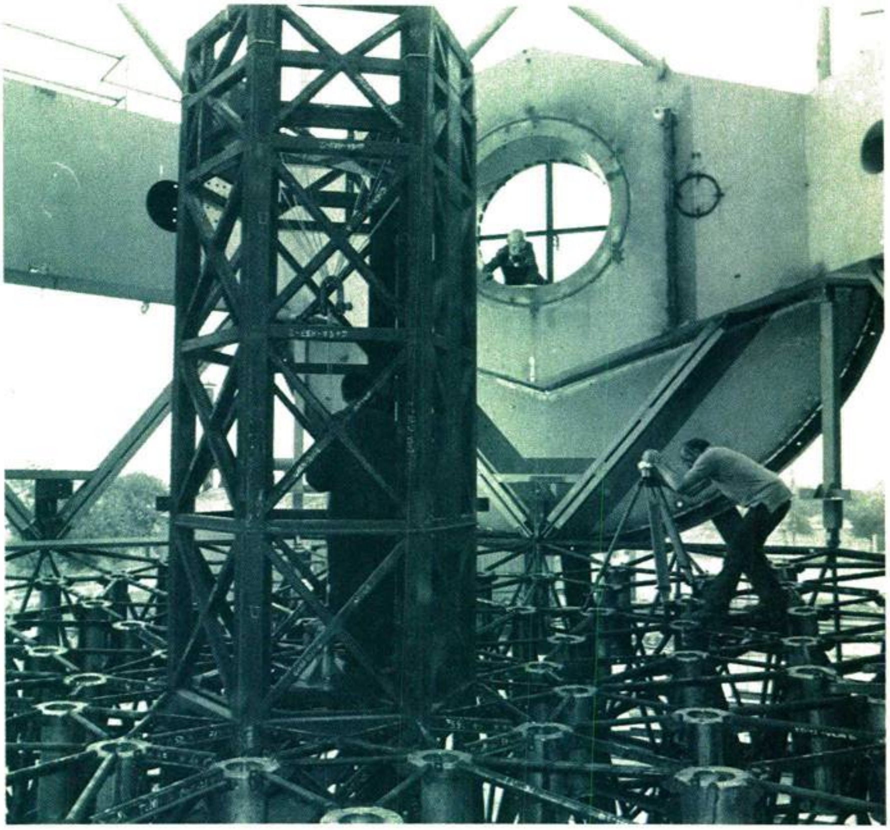
rors, were recently completed at Itek Optical Systems in Lexington, Massachusetts. Optical tests show that the completed segments concentrate 80 percent of the light they receive into an image about one-half of an arcsecond in diameter. The Keck telescope's primary mirror segments will be aligned and held accurately in place by computer control.

The Keck telescope is a joint project of the University of California and the California Institute of Technology. When completed in 1991, the Keck telescope is expected to be the world's most powerful ground-based optical and infrared telescope.



WORKERS PREPARE the steel framework for the mirror cell of the 10-meter Keck telescope for shipment to the observatory on Mauna Kea in Hawaii.

DISTANT SUPERNOVA MAY HAVE COSMOLOGICAL IMPACT

Astronomers have detected the most distant supernova ever seen in a faint galaxy cluster over 4 billion light-years from Earth. The discovery raises hopes that astronomers may one day be able to accurately measure the rate at which the expansion of the universe is slowing down.

The researchers — Hans Norgaard-Nielsen, Leif Hansen, and Henning Jorgensen from Denmark; Alfonso Aragon Salamanca and Richard Ellis from the United Kingdom; and Warrick Couch from Australia — discovered the supernova, designated 1988U, during an ongoing search for supernovae in distant galaxies.

Since 1986, they have monitored approximately sixty galaxy clusters in the redshift range of 0.2 to 0.5 (corresponding to distances of about 3 billion to 6 billion light-years) with the 1.5-meter Danish telescope at La Silla, Chile. Approximately once a month for eight months out of the year, they have taken one-hour CCD exposures of each cluster, which they then subtract from a reference image of the same cluster. If a supernova is present, it shows up as a bright spot in the subtracted image.

Supernova 1988U first appeared on an image made August 8, 1988. Subsequent observations with the Danish telescope and the 4.2-meter William Herschel Telescope on the Canary Islands showed that the supernova was fading at a rate typical of Type Ia supernovae, and spectra taken with the Anglo-Australian Telescope confirmed that 1988U lay at the same distance as the galaxy cluster.

Type Ia supernovae are important to cosmologists because they all give off approximately the same amount of light at peak brightness. This absolute brightness is one of four critical factors that determine how bright a supernova appears from Earth. The other three factors are how far away the supernova is, how much the supernova's light is attenuated by intervening dust, and how rapidly the expansion of the universe is slowing.

Fortunately, astronomers know the absolute brightnesses of Type Ia supernovae and can easily measure their apparent brightnesses. The amount of attenuation in the supernova's light can be determined accurately from observations of nearby Type Ia supernovae. And the comparative distances to distant supernovae can be learned by measuring their redshifts spectroscopically. That leaves the universe's deceleration rate as the only unknown factor.

A supernova in an open universe, a universe that will expand forever, will appear fainter than a supernova in a closed universe, a universe that will eventually slow down, stop, and then contract. The deceleration rate's effect on the apparent magnitude of a supernova grows the farther away the supernova is. At a redshift of 0.5, the difference between a supernova in an open universe with a constant rate of expansion and one in a universe on the borderline between open and closed is 0.28 magnitudes. Because the difference is quite small, a large number of supernovae at great distances must be studied to learn the fate of the universe.

The researchers estimate that they need to observe about fifteen Type Ia supernovae at an average redshift of 0.5 to pin down the deceleration rate, a process they expect will take several years.

1989 ENDS WITH A LEAP SECOND

If New Year's Eve seems a little long this year, there's good reason: the International Earth Rotation Service, the body that coordinates timekeeping for all countries, has announced that 1989 will be exactly one full second longer than a normal year. This is to make sure that terrestrial timekeeping systems remain in close step with Earth's rotation, which is gradually slowing down.

The leap second, which will be designated 23h59m60s, will be interposed between 23h59m59s universal time on December 31, 1989, and 0h0m0s UT on January 1, 1990.

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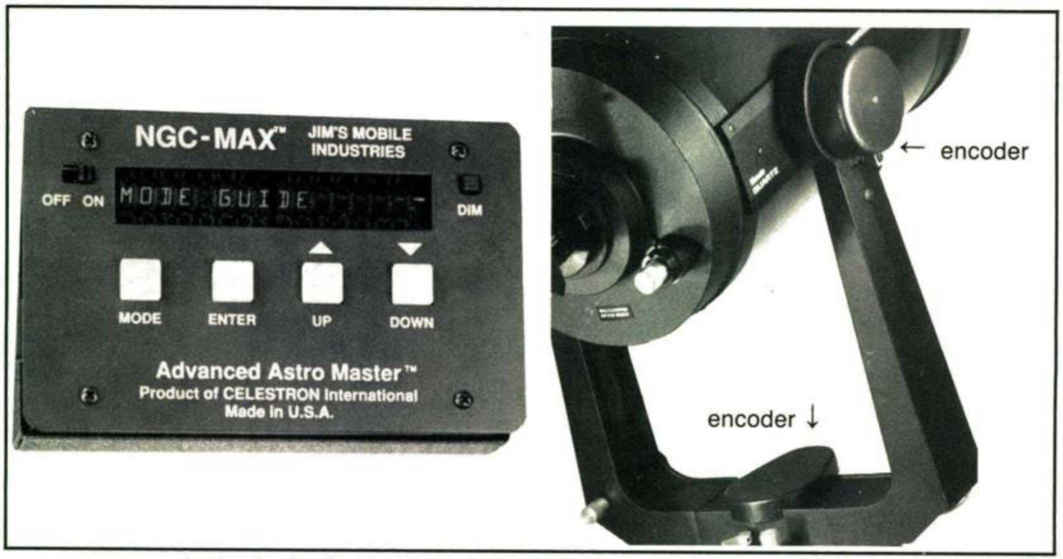

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Space News

HOW A STAR IS BORN

The birth of a star, as astronomers currently understand it, is a paradoxical process. Gas within a molecular cloud is disrupted and begins to fall in on itself, collapsing and condensing to the point where a star is created. But the nature of the gas within the cloud — primarily hydrogen and helium — prevents the collapse from getting to that point; the gas gets so hot that its pressure counteracts the force of gravity and halts the collapse.

For a star to form, more of the heat must escape so that the cloud can further condense. But what allows the heat to escape? A team of astronomers will attempt to answer that vexing question with a satellite experiment designed to measure certain kinds of atoms and molecules suspected to aid in the cooling process

Called the *Submillimeter Wave Astronomy Satellite*, the project is one of four experiments selected as part of NASA's revitalized Small Explorer program, a series of small- to medium-sized payloads that will be launched in the next few years using Scout expendable rockets. The submillimeter satellite is scheduled for launch in December 1993 from a platform in the Indian Ocean off the coast of Kenya.

The research team, led by Gary Melnick of the Harvard-Smithsonian Center for Astrophysics, will be looking at the abundance of water, molecular oxygen, atomic carbon, and isotopic carbon monoxide in galactic clouds. The satellite will scan the clouds in search of these four atomic and molecular species, thought to help cool clouds so that they can form stars.

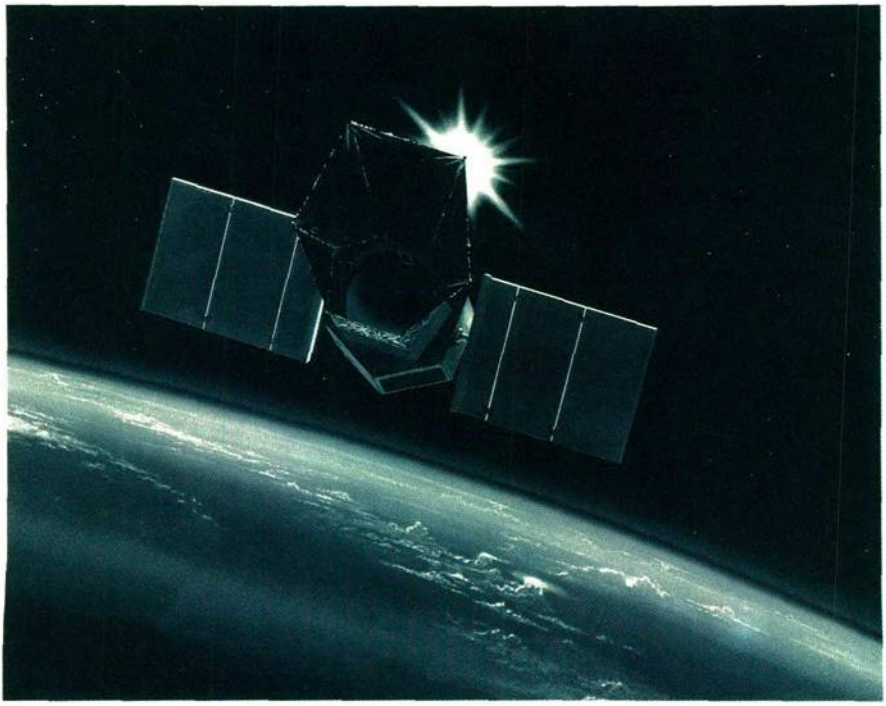
It is necessary to study these chemicals, particularly water and molecular oxygen, from space because atmospheric absorption prevents astronomers from detecting them clearly with ground-based telescopes. Submillimeter telescopes are particularly good at detecting the wavelengths emitted by the universe's cooler regions, such as star-forming clouds, which usually range from 10 to 40 kelvins.

These chemicals are important to star formation because they can be excited at the low temperatures prevalent in gas clouds. Once excited, they release energy, thus helping cool the cloud. While species other than hydrogen and helium are thought to occur at only 1 part in 10,000 or less within a cloud, these four candidates are believed to be relatively abundant. The major constituents of gas clouds, molecular and atomic hydrogen, are thought to be inefficient at cooling clouds because they require much higher temperatures to become excited and radiate energy.

The satellite will scan thousands of clouds within the galactic plane to measure the abundances of these chemicals. Using a 55-centimeter off-axis Cassegrain antenna and a spectrometer, the satellite will look at clouds in Orion, Taurus, Ophiuchus, and Perseus. Projected to cost about $30 million, the satellite will stay in orbit for up to three years.

Melnick is collaborating with other researchers from the Center for Astrophysics as well as scientists from the National Air and Space Museum, the University of Massachusetts, the University of Cologne, the University of California at Berkeley, and NASA's Ames Research Center. NASA's Goddard Space Flight Center will build the spacecraft.

The trip will be worthwhile even if the telescope detects nothing, Melnick said. "If we detect no water or oxygen, this will contradict almost all current theories of the chemical composition of these clouds and will represent a major new puzzle to be solved." — *Karen Hartley*



PIERCING INTERSTELLAR CLOUDS and the secrets of star formation is the goal of the *Submillimeter Wave Astronomy Satellite* to be launched in 1993.

SOVIET CREW RETURNS TO MIR SPACE STATION

After four months on automatic pilot, the Soviet Union's *Mir* space station is manned once again. Two cosmonauts, Alexander Viktorenko and Alexander Serebrov, arrived at the station on September 8 for a five-month stay that will see two new modules added to the orbiting spacecraft.

The first module, scheduled for launch in October, includes a shower and a new manned maneuvering unit, which is similar to the one U.S. astronauts use to move around outside the space shuttle. The second module, due in February 1990, will carry a docking port for the Soviet *Buran* space shuttle.

The new crew will also install a solar panel on the *Kvant* astrophysical observatory module to increase the electrical power available to the module. (See "Soviet Station Probes the Universe," September 1989.) A second cosmonaut crew is expected to replace Viktorenko and Serebrov in February.

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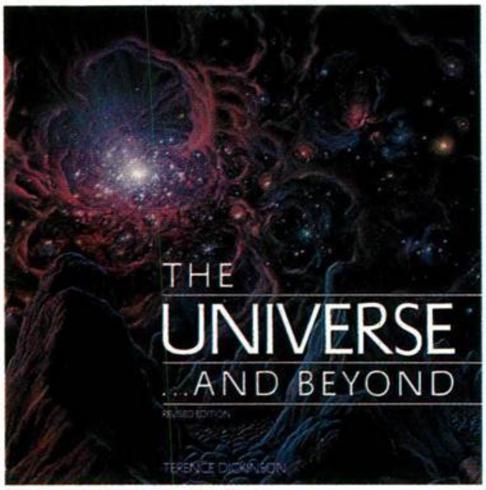
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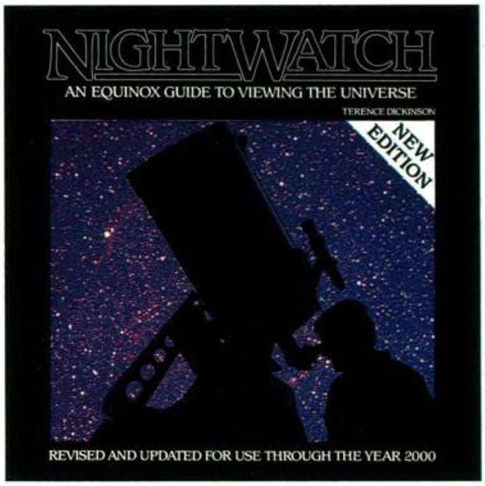
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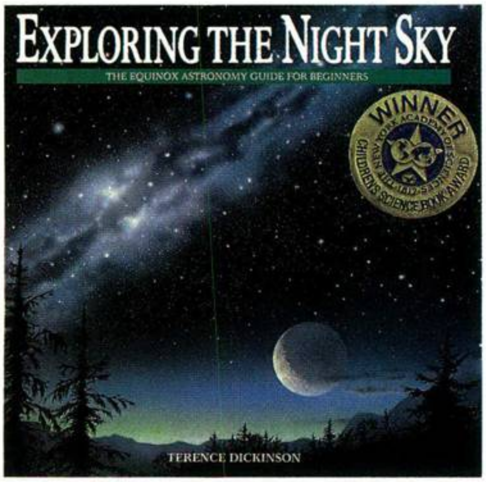
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Amateur News

ASTROFEST WHETS AMATEUR SPIRIT

Three-hundred-and-fifty enthusiastic amateur astronomers and telescope makers braved gray skies and sodden ground to show off their telescopes and talk astronomy at Camp Sha-Wa-Na-See near Kankakee, Illinois, on the weekend of September 8 and 9, 1989. Despite heavy rain on Friday night, the telescope field was dry enough for telescopes on Saturday. Vehicles, however, often got bogged down in mud and had to be pushed out. Although the sky looked like it might clear off Saturday afternoon, it rained again Saturday night.

Fit for any weather was Bill Volna's portable observatory. The small cabin carries a 6-inch f/10 refractor on one side; the observer, seated inside the cabin, looks through the telescope and points it by turning the entire observatory with manual controls or a motor drive. The cabin is equipped with adjustable red and white lighting, a computer, a small radio, and a heater. Last winter, Volna said, he observed in comfort when the temperature was −17 degrees Fahrenheit. An engineer by profession, Volna designed and built virtually every component of his portable observatory.

Widely admired was Doug Kasel's massive 16-inch binocular. Finished only days before the meeting, Kasel reported that in a test run the telescope had performed as planned — "it focuses, merges, and stays put." To complete the binocular, Kasel tackled and solved the tricky problem of aligning two 16-inch optical systems with independently tiltable and rotatable upper-end units.

An equally pleased Bill Benesch watched the sky for "sucker holes" to demonstrate the exceptional performance of his solar telescope. In this telescope, a small amount of sunlight — about 1 part in 100,000 — passes through an Inconel-coated precision optical window at the front of the tube. Behind this is a paraboloidal mirror that reflects the light back toward the window; the window reflects this light back to a focus beside the mirror. This system, because it is both unobstructed and closed, gives exceptionally high-quality images of the Sun.

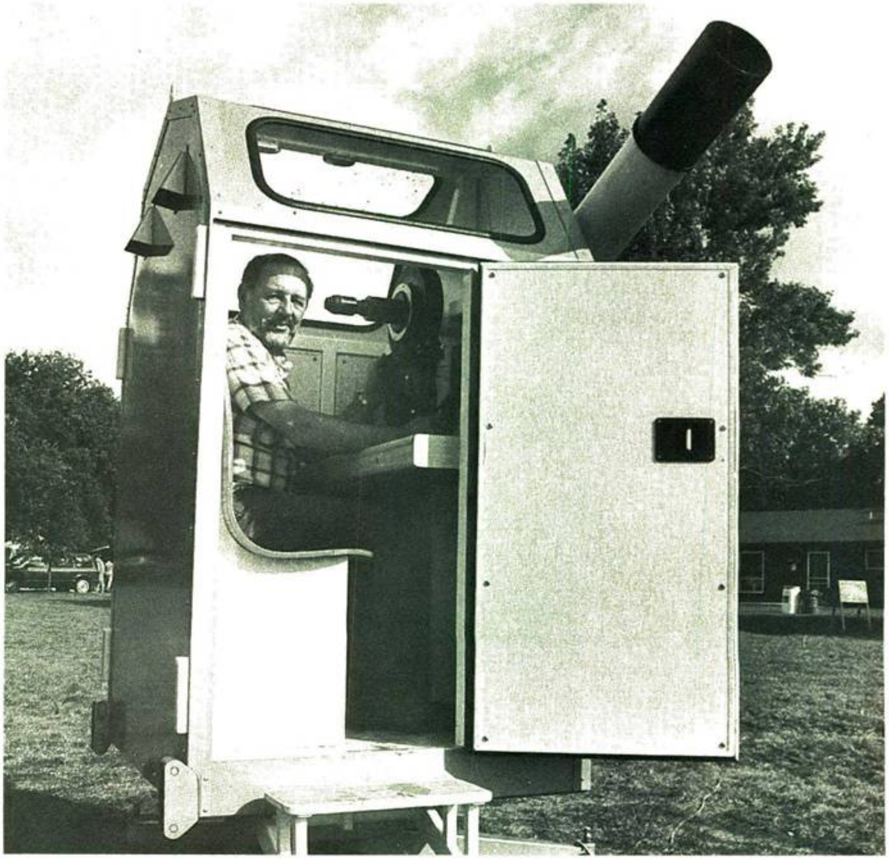
Sue and Alan French displayed their massive Dobsonian refractor. The 8-inch f/11.5 instrument has an apochromatic objective made by Roland Christen. A massive pier a foot in diameter supports the instrument's Dobsonian cradle roughly eight feet off the ground. The telescope moves with the light touch of a finger. The Frenches are well-known telescope makers.

David Kriege (see "The New Generation of Dobsonians" by Richard Berry, April 1989) brought telescopes of 18- and 25-inches aperture. The 25-incher, which he calls "Obsession 2," can be set up in five minutes because it uses a clever system of twist-lock poles to support the upper end. "Obsession 3," his latest creation, boasts an exceptionally fine 18-inch mirror. Kriege has found that Wilsonart 4552-50 counter top covering — a rather rough pebble-textured material — gives lower friction on Teflon than any other bearing material he knows.

Perhaps because there were fewer telescopes set up than normal, AstroFest-goers embraced the swap meet with unusual fervor. Although scheduled to begin at 9 a.m., swapping and selling used goods and "junque" was in full swing by 8 a.m. — before many of the campers at Astrofest even woke up. Most of the good bargains were gone by 10 a.m.

After-dinner speaker Stephen J. Edberg of the International Halley Watch evoked "the crazy years" Comet Halley brought the world of astronomy. Reviewing Halley's apparition, Edberg also touched on the societal foibles and mercantile follies — from Comet Rum to Halleyscopes — the comet sparked. He also described why Halley disappointed so many observers: although it peaked in brightness in April, the comet looked best in March. In April, he explained, Earth-bound observers looked straight down Halley's tail, so the comet appeared round and featureless. In March it sported a broad, fan-shaped tail.

Astrofest 1989 proved once again, as it does every year, that amateur astronomy and telescope making are alive and thriving in the Midwest. A full report on the 1989 AstroFest appears in *Telescope Making #38.* ☐



SNUG AS A BUG in his heated portable observatory, Minnesotan Bill Volna showed amateur astronomers a better way to observe at the 1989 Astrofest meeting held September 8 and 9.

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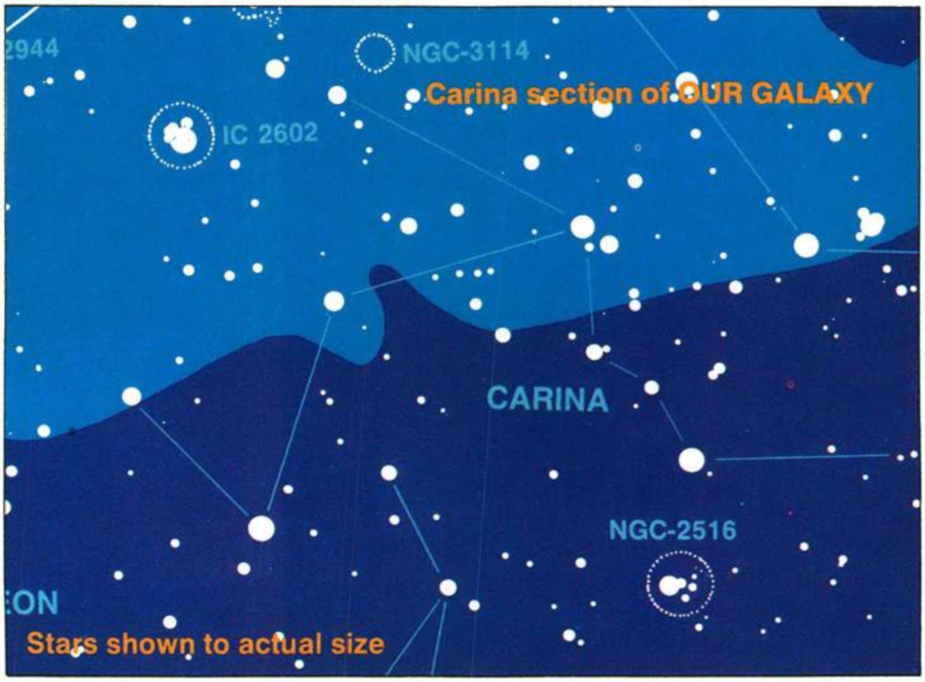
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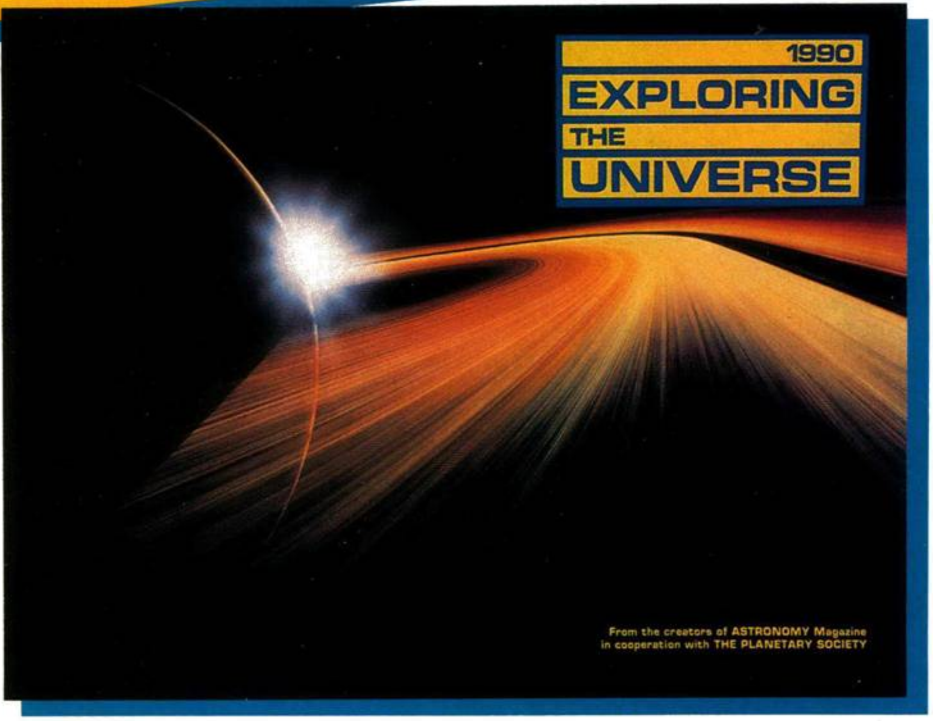
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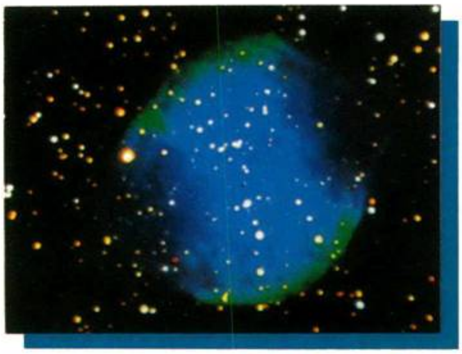

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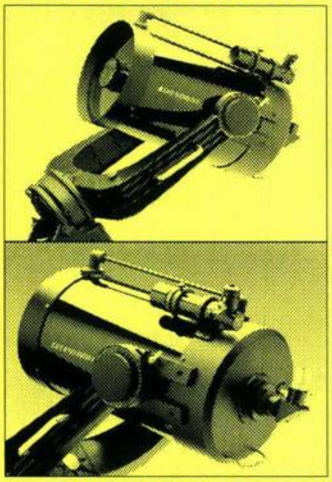

Complete 11-inch aperture, f/10 (280mmA, 2,800mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group on the optical surfaces, and a manual-positioning handle mounted on the rear cell; counterweight bar assy; widefield 8x50mm right-angle/straight-thru (convertible) Finderscope with built-in illuminated polar-alignment reticle; 2.0" mirror star diagonal, with 1.25" adapter; 30mm (93x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 17mm (165x), 1.25" barrel, multi-coated, premium-grade, high-power Plossl eyepiece; massive, heavy-duty Dual-Fork Astronomical Mount with oversize bearings and deeply-ribbed fork tines with chromed carrying/positioning handles; giant graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N hemisphere *only*), precision 7.5" diameter worm-drive gearing, ***and field-rechargeable battery for completely cordless operation,*** all built into "drive-base"; car-battery power-cord/plug; universal AC-adapter/battery- charger; deluxe, heavy-duty, adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale and bubble level; deluxe, heavy-duty, adjustable Field Tripod with positive, all-metal leg locks and 2" dia., upper leg sections for maximum rigidity, rubber-coated for vibration damping; anti-vibration footpads for tripod; Dust Covers for optical apertures; large, deluxe, extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; Instruction Manual; limited lifetime warranty. Some assembly required.

Ultima C11, StrBrt, Wedge, Tripod (as above) .... (List: $ 5,390) .... CALL

Ultima C8

Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group on the optical surfaces, and a manual-positioning handle mounted on the rear cell; widefield 8x50mm right-angle/straight-thru (convertible) Finderscope with built-in illuminated polar-alignment reticle; 1.25" visual accessory holder; 1.25" multi-coated prism star diagonal; 30mm (68x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 7mm (290x), 1.25" barrel, fully coated, premium-grade, high-power Orthoscopic eyepiece; massive, heavy-duty Dual-Fork Astronomical Mount with oversize bearings and deeply-ribbed fork tines with chromed carrying/positioning handles; giant graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N hemisphere *only*), precision 7.5" diameter worm-drive gearing, ***and field-rechargeable battery for completely cordless operation,*** all built into "drive-base"; car-battery power-cord/plug; universal AC-adapter/battery-charger; deluxe, heavy-duty, adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale and bubble level; deluxe, heavy-duty, adjustable Field Tripod with positive, all-metal leg locks and 2" dia., upper leg sections for maximum rigidity, rubber-coated for vibration damping; Dust Covers for optical apertures; large, deluxe, extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; Instruction Manual; limited lifetime warranty. Some assembly required.

Ultima C8, StrBrt, Wedge, Tripod (as above) ...... (List: $ 3,398) .... CALL

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PowerStar IV C8

Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group; DewStar lens-shade; widefield 8x50mm right-angle Finderscope with built-in illuminated polar-alignment reticle; 1.25" visual accessory holder; 1.25" star diagonal; 30mm (68x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 7mm (290x), 1.25" barrel, fully coated, premium-grade, high-power Orthoscopic eyepiece; Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N ***or*** S hemisphere) and precision 7.5" diameter worm-drive gearing, built into "drive-base"; DC battery-pack *(batteries **not** included);* car-battery power-cord/plug; universal AC power adapter, cord & plug; Drive Corrector Hand Control Unit, with additional controls and connectors for optional accessory electronic equipment; deluxe adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale, bubble level and no-tool knob set; adjustable-height Field Tripod; Dust Covers for optical apertures; extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; T-Adapter; Piggyback Mount; Instruction Manual; Product Guide and Reference Manual; limited lifetime warranty. Some assembly required.

PwrStr IV C8, StrBrt, Wedge, Tripod (as above) (List: $ 2,998) .... CALL

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Classic C8

The Classic C8 is the perfect telescope for the budget-minded buyer. Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly; widefield (8.0° field-of-view) 6x30mm straight-through Finderscope; 1.25" visual accessory holder; 1.25" prism star diagonal; 25mm (81x), 1.25" barrel, multi-coated, Kellner eyepiece; Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 110V 60 Hz AC electric motor-drive tracking system (for N hemisphere *only*) built into telescope "drive-base"; AC power cord; adjustable Equatorial Wedge; adjustable-height Field Tripod; Dust Covers for optical apertures; Instruction Manual; limited lifetime warranty. StarBright optical coatings group is optionally available at extra cost. Some assembly required.

Classic C8, Wedge, Tripod (as above) .... (List: $ 1,956) .... CALL
Classic C8, StrBrt, Wedge, Tripod (as above) .... (List: $ 2,096) .... CALL

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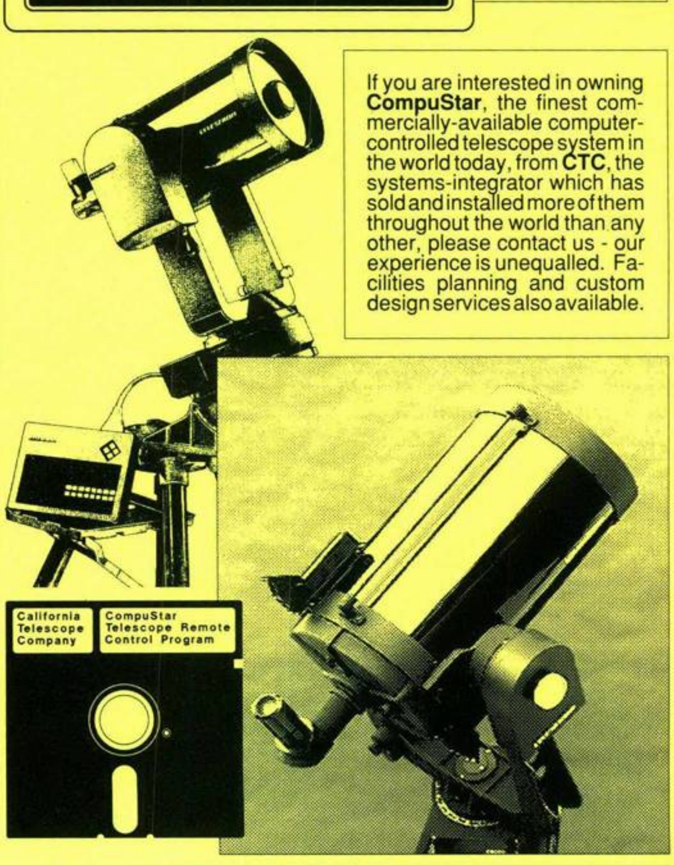

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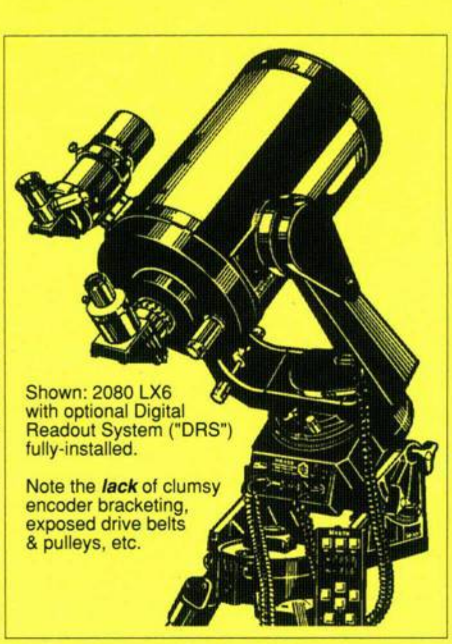
2080 2120 LX6's


Shown: 2080 LX6 with optional Digital Readout System ("DRS") fully-installed.

Note the ***lack*** of clumsy encoder bracketing, exposed drive belts & pulleys, etc.

Meade's new LX6's boast an *f*/6.3 optical system which permits astrographic exposures in only four-tenths of the time required by an *f*/10 system! In addition, they come complete with quartz-locked, micro-computer-controlled, electronic pulse-motor drive, sophisticated hand control unit with astrographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, giant 9x60mm finderscope, built-in provision for optional DRS or CAT system, and more!

STANDARD FEATURES & FACTORY-SPECIFIED EQUIPMENT:

Complete *f*/6.3 telescope tube assembly (8" or 10" aperture, 1,280mm or 1,600mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (49x or 62x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz-locked, micro-computer-controlled, electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit (note: Meade's Digital Readout System is an ***optional*** accessory); 115Vac/60Hz power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale, bubble level and magnetic compass; ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty

2080 LX6	(List:$4,400)	CALL
2120 LX6	(List:$6,400)	CALL

(These 'Scopes also available with optional new Heavy-Duty Wedge)

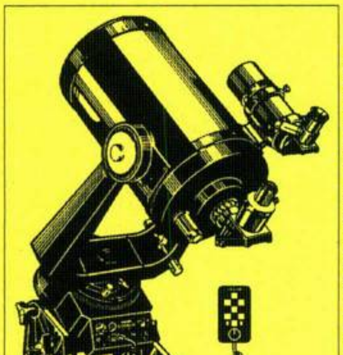
Package: Telescope *and* Optional Digital Readout System, together:

2080 LX6, *with* Mod. 9068 DRS	(List:$5,100)	CALL
2120 LX6, *with* Mod. 9070 DRS	(List:$7,100)	CALL

FREE FREIGHT! (UPS Ground) for the LX6's above

Meade's CAT's and DRS's are bolt-on, plug-in units. They can be installed by anyone who is comfortable using simple hand tools. However, if you are concerned about mechanical or electronic assembly, we offer installation services for our telescope customers when the telescope and digital accessories are purchased at the same time. Please contact us for information, details and pricing.

Meade LX5's



Fully equal to LX6's in terms of their standard equipment, they come complete with quartz-lock microelectronic pulse motor drive, sophisticated hand control unit with photographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces,

& giant 9x60mm finderscope!

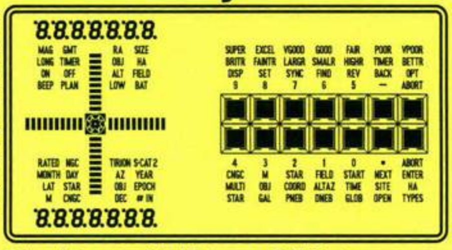
Specs: 2080 LX5 and 2120 LX5: Complete 8"A (2080 LX5) or 10"A (2120 LX5) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz micro-electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.

2080 LX5, Wedge, Tripod (as above)	(List: $ 3,800)	CALL
2120 LX5, Wedge, Tripod (as above)	(List: $ 5,400)	CALL

FREE FREIGHT! (UPS Ground) for the LX5's above

Meade's CAT System

Meade's **C**omputer-**A**ided **T**elescope (the "CAT") system has most of the advantages of a computer-***controlled*** telescope at only a fraction of the cost. The CAT can readily and quickly help you find any of the thousands of celestial objects whose coordinates and other descriptive data are stored in its memory, ***including all of the planets***, as well as any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The CAT is loaded with extra features and functionality as the panel legends, at right, indicate.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For the computer-literate, there is also a version of the CAT with an RS-232C port (the "CAT-COM") for connection to a "PC"-type personal computer. CAT-COM includes 4 demo programs, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software (source & executable) is supplied on a 5.25" 360Kby disk.

Optional Computer-Aided Telescope (CAT) System:

CAT, 2080 *or* 2120 LX6	(List: $1,590)	CALL
CAT-COM, 2080 *or* 2120 LX6	(List: $1,850)	CALL

Package: Telescope *and* Optional CAT System, together:

2080 LX6 *with* CAT	(List: $5,990)	CALL
2080 LX6 *with* CAT-COM	(List: $6,250)	CALL
2120 LX6 *with* CAT	(List: $7,990)	CALL
2120 LX6 *with* CAT-COM	(List: $8,250)	CALL
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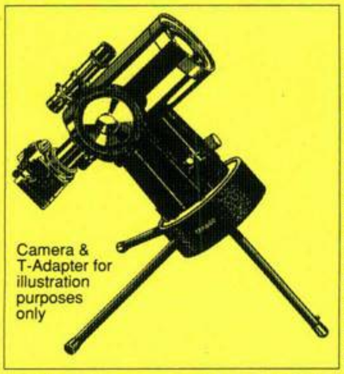
2045-D(igital)


Camera & T-Adapter for illustration purposes only

This is Meade's go-anywhere, do-anything telescope. Small and light enough to maximize its portablity, it nevertheless has sufficient aperture and focal length to permit enjoyable astronomical viewing. And, the new 12VDC drive system permits it to be operated worldwide (N or S hemisphere, too) from a small battery pack. It can also double as a high-quality terrestrial spotting scope or telephoto camera lens.

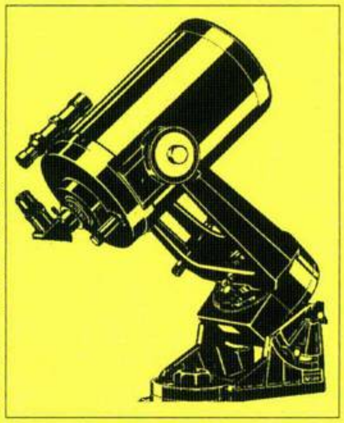
Specs: 2045-D: Complete Schmidt-Cassegrain telescope tube assy (f/10, 102mmA, 1,000mmF) with certified diffraction-limited optical system; high-transmission anti-reflection coatings on corrector plate; ultra-smooth anti-back-lash focuser; 5x24mm finderscope; 1.25" prism-type stardiagonal/eyepiece holder; 25mm eyepiece (40x); rugged dual-fork astro mount, with DC digital-electronic tracking motor built into base and N-S hemisphere switch; graduated setting circles, manual positioning controls & clutches on both axes of motion; tabletop tripod legs (adjustable for latitude); dust covers; DC power cord and battery pack (batteries ***not*** included); instructions; limited lifetime warranty.

Please inquire regarding availability of Tripod, Wedge, Carrying Case, etc.

2045-D, HTC (as above)	(List: $ 1,300)	CALL

FREE FREIGHT! (UPS Ground) for the 2045-D above

Meade 2080



Specs: Standard 2080-A: Complete 8"A f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm aperture, 2,000mm focal length); 6x30mm viewfinder; 1.25" eyepiece holder; 1.25" prism-type star diagonal; 25mm (80x) MA eyepiece, 1.25" barrel; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; AC hysteresis-synchronous tracking motor and worm-drive gearing built into telescope drive base; 115Vac 60Hz AC power cord; Equatorial Wedge with no-tool knob set; adjustable-height Field Tripod; dust covers for optical apertures; instruction manual; limited lifetime warranty.

Specs: Standard 2080-B: The "B" model includes all above, plus MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors, for increased image brightness, contrast and clarity.

Premium Accessory Upgrade: Either of the telescopes above is available with the following premium accessories substituted: giant 9x60mm illuminated-reticle polar-alignment viewfinder; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000, 26mm Super Plossl eyepiece, 1.25" (77x);

2080-A, Wedge, Tripod (as above)	(List: $ 1,738)	CALL
2080-A, *plus* Premium Accessory Package	(List: $ 2,238)	CALL
2080-B, MCOG, Wedge, Tripod (as above)	(List: $ 1,858)	CALL
2080-B, *plus* Premium Accessory Package	(List: $ 2,358)	CALL

FREE FREIGHT! (UPS Ground) for the 2080's above

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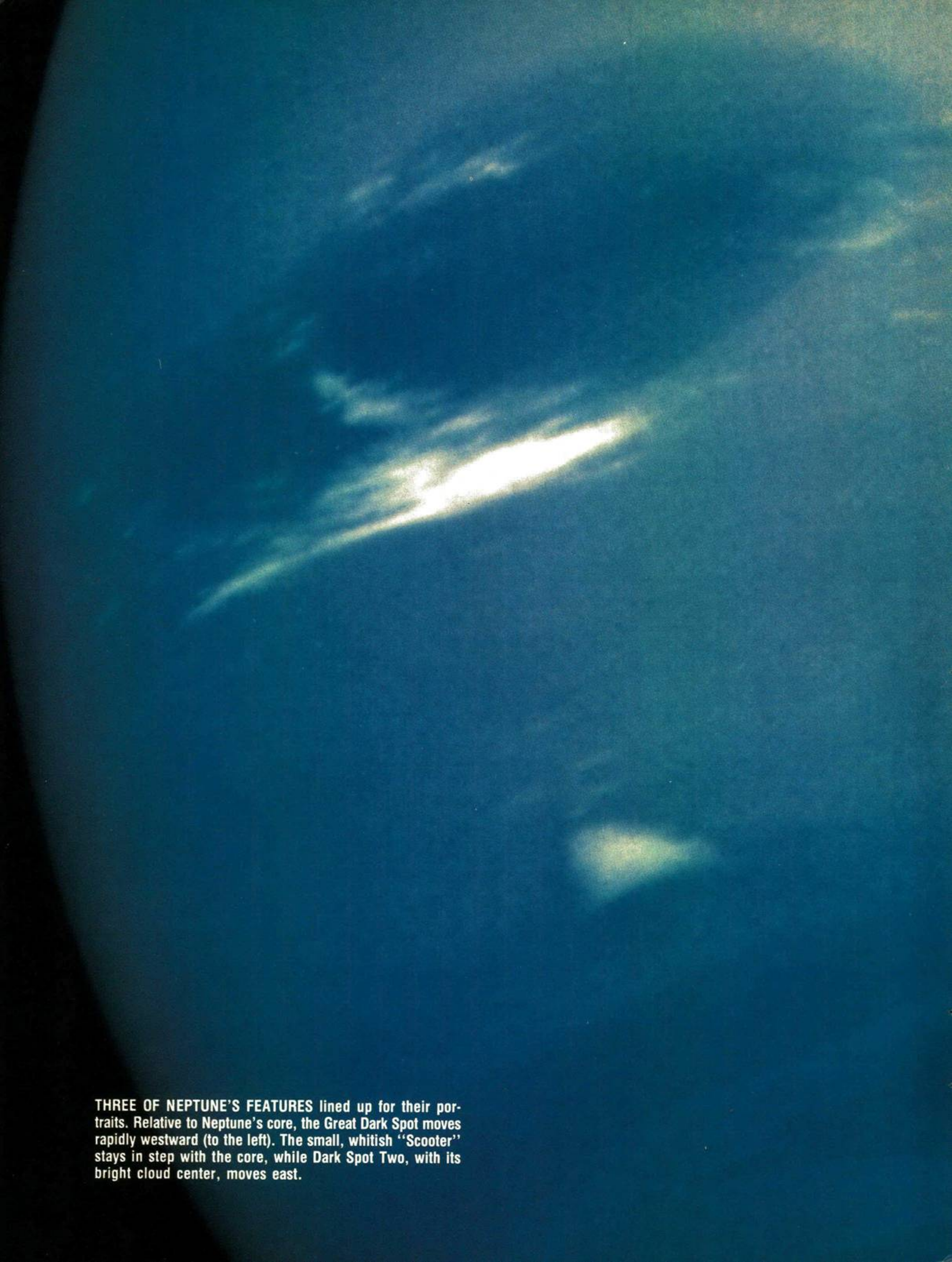
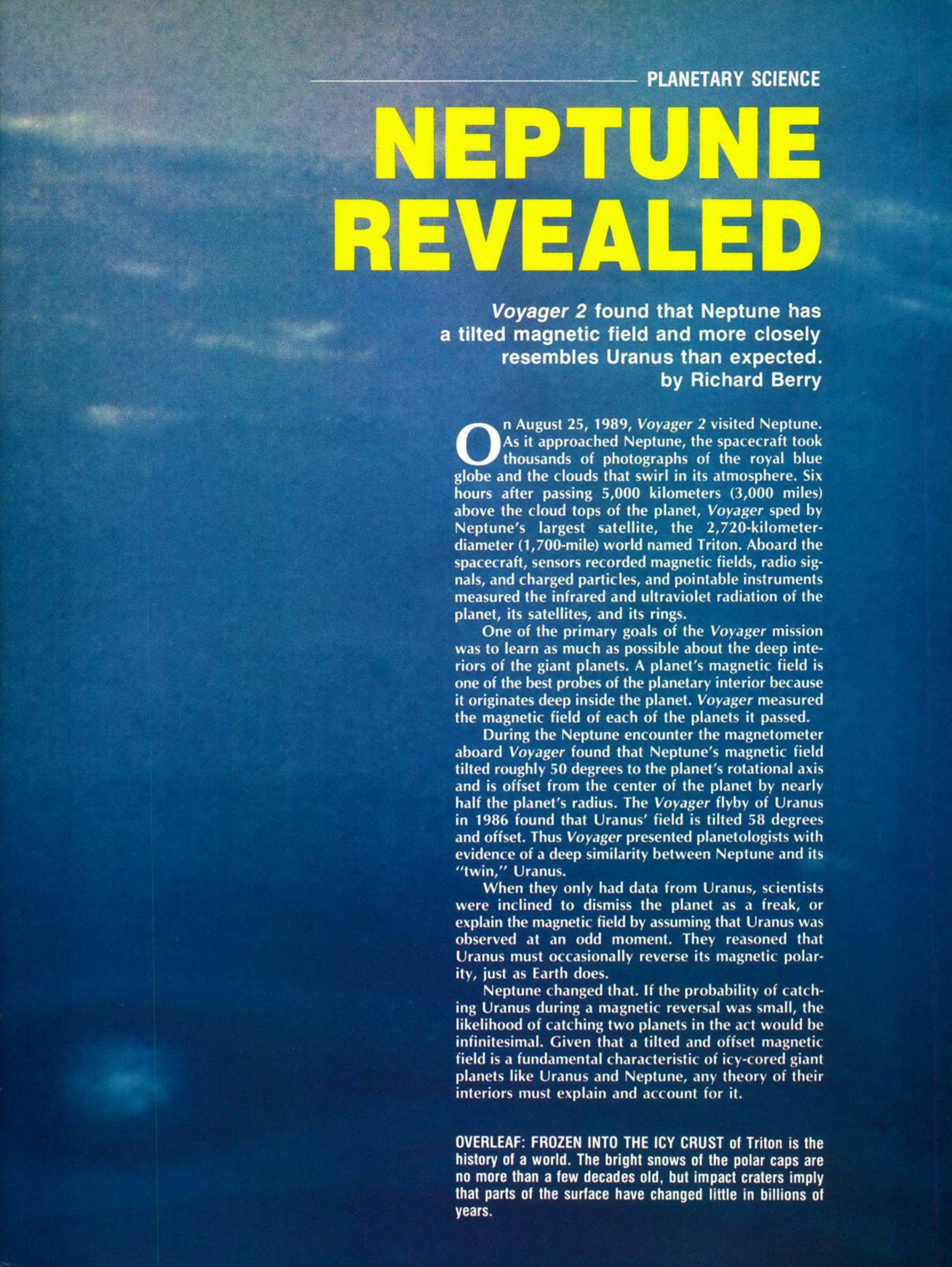


THREE OF NEPTUNE'S FEATURES lined up for their portraits. Relative to Neptune's core, the Great Dark Spot moves rapidly westward (to the left). The small, whitish "Scooter" stays in step with the core, while Dark Spot Two, with its bright cloud center, moves east.



NEPTUNE REVEALED

Voyager 2 **found that Neptune has a tilted magnetic field and more closely resembles Uranus than expected.**

by Richard Berry

On August 25, 1989, *Voyager 2* visited Neptune. As it approached Neptune, the spacecraft took thousands of photographs of the royal blue globe and the clouds that swirl in its atmosphere. Six hours after passing 5,000 kilometers (3,000 miles) above the cloud tops of the planet, *Voyager* sped by Neptune's largest satellite, the 2,720-kilometer-diameter (1,700-mile) world named Triton. Aboard the spacecraft, sensors recorded magnetic fields, radio signals, and charged particles, and pointable instruments measured the infrared and ultraviolet radiation of the planet, its satellites, and its rings.

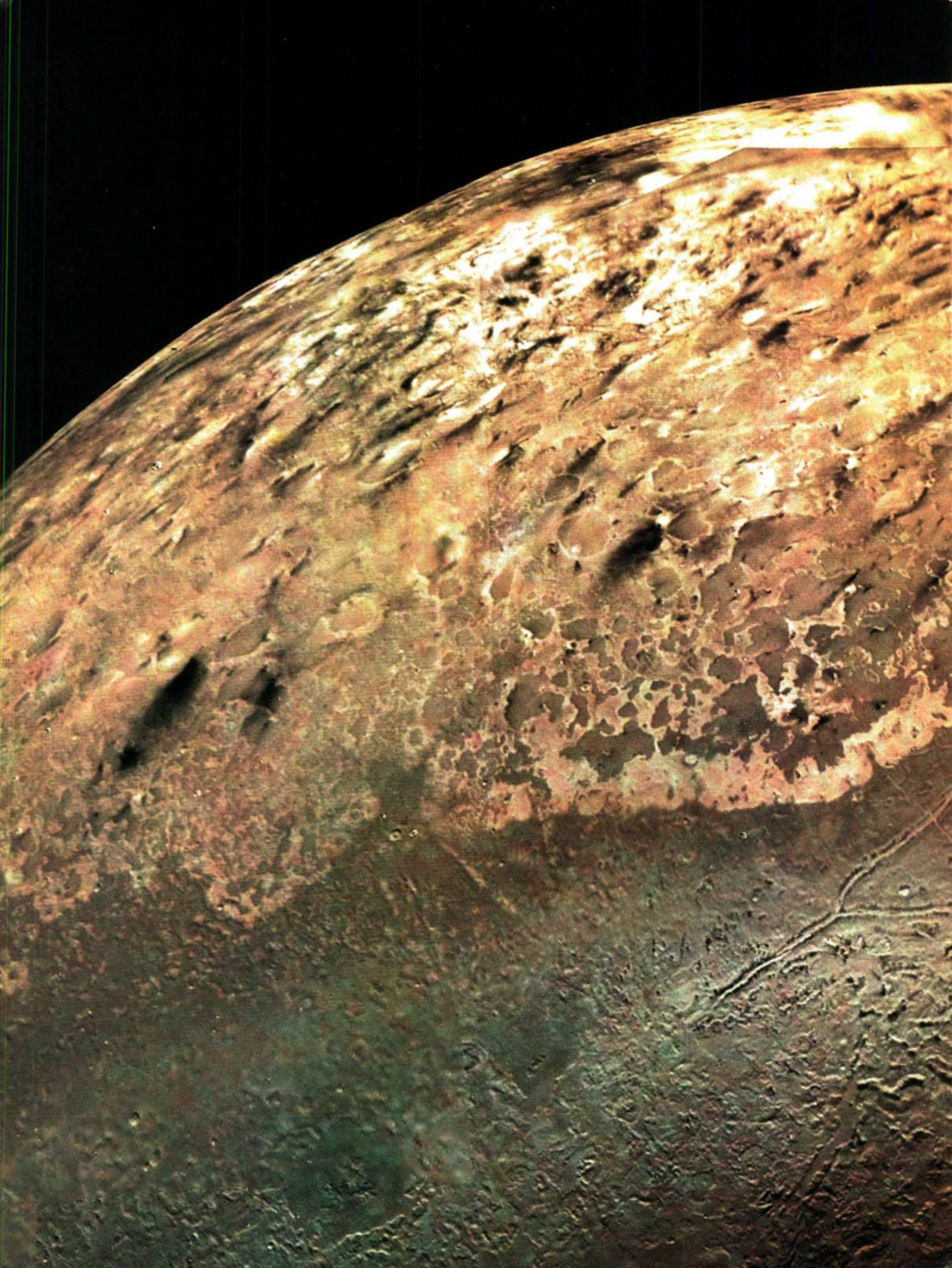
One of the primary goals of the *Voyager* mission was to learn as much as possible about the deep interiors of the giant planets. A planet's magnetic field is one of the best probes of the planetary interior because it originates deep inside the planet. *Voyager* measured the magnetic field of each of the planets it passed.

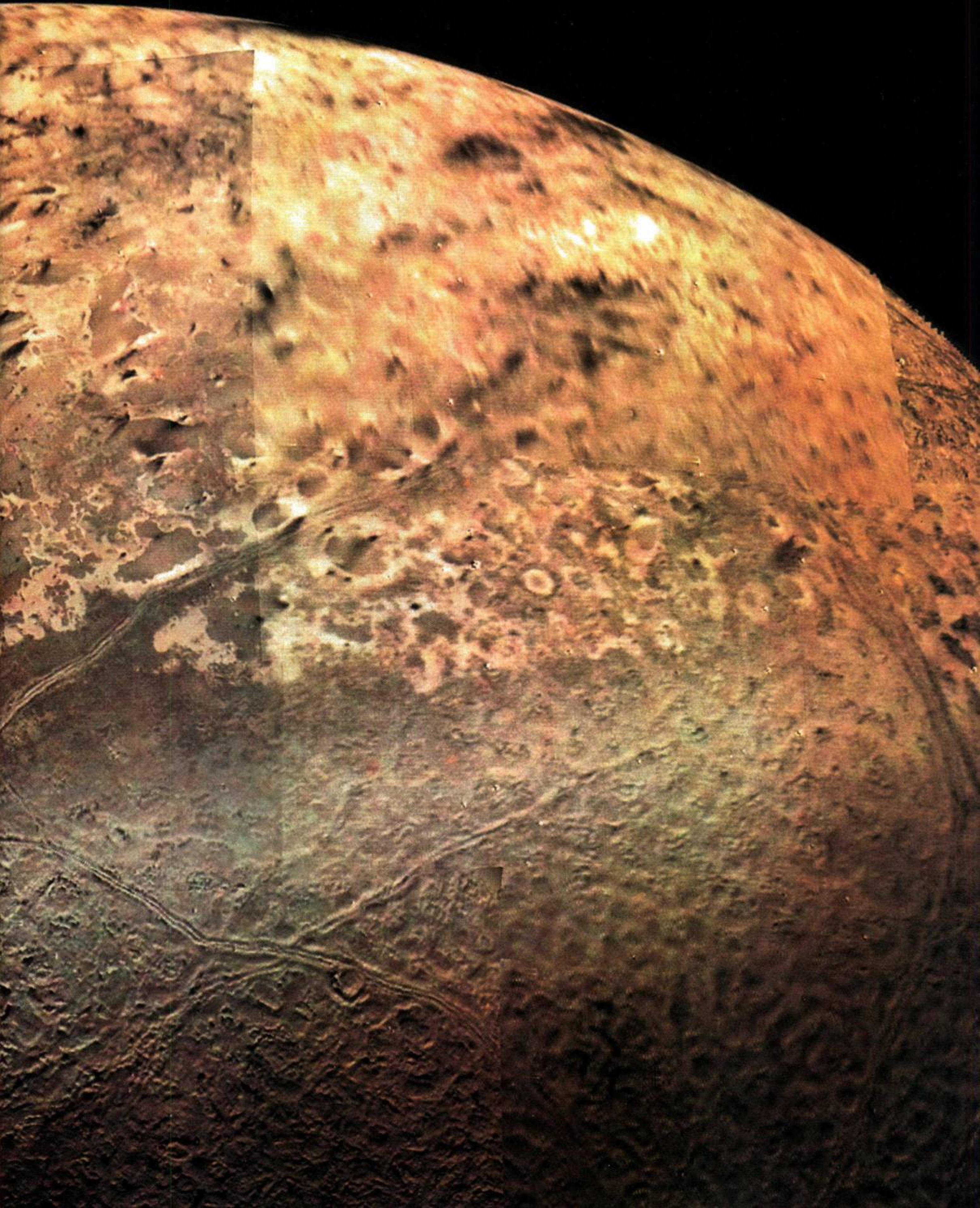
During the Neptune encounter the magnetometer aboard *Voyager* found that Neptune's magnetic field tilted roughly 50 degrees to the planet's rotational axis and is offset from the center of the planet by nearly half the planet's radius. The *Voyager* flyby of Uranus in 1986 found that Uranus' field is tilted 58 degrees and offset. Thus *Voyager* presented planetologists with evidence of a deep similarity between Neptune and its "twin," Uranus.

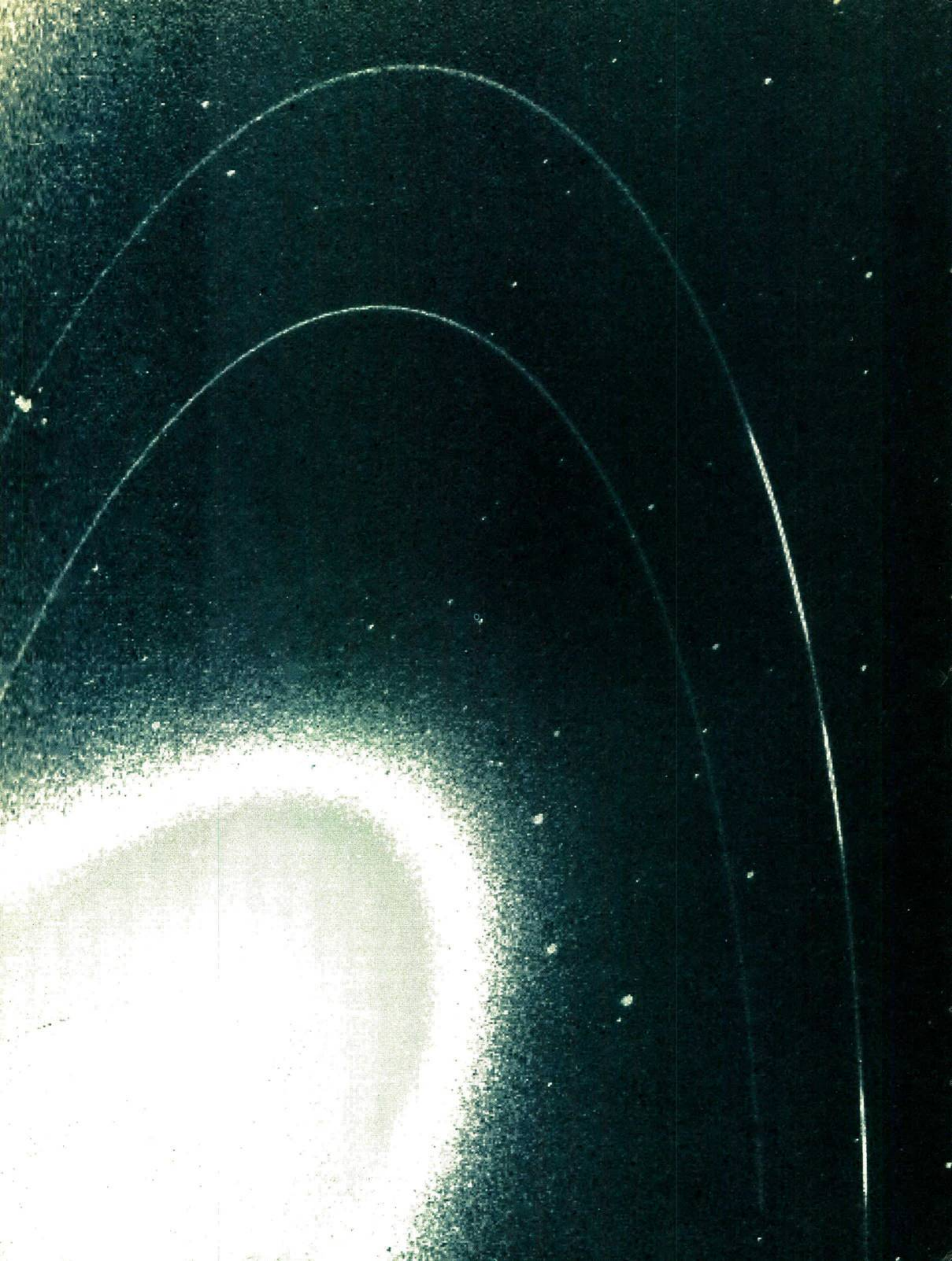
When they only had data from Uranus, scientists were inclined to dismiss the planet as a freak, or explain the magnetic field by assuming that Uranus was observed at an odd moment. They reasoned that Uranus must occasionally reverse its magnetic polarity, just as Earth does.

Neptune changed that. If the probability of catching Uranus during a magnetic reversal was small, the likelihood of catching two planets in the act would be infinitesimal. Given that a tilted and offset magnetic field is a fundamental characteristic of icy-cored giant planets like Uranus and Neptune, any theory of their interiors must explain and account for it.

OVERLEAF: FROZEN INTO THE ICY CRUST of Triton is the history of a world. The bright snows of the polar caps are no more than a few decades old, but impact craters imply that parts of the surface have changed little in billions of years.







The most plausible explanation centers on the location of the conductive layers inside the planet. The magnetic field inside Earth arises in fluid motions within the electrically conductive nickel-iron core of the planet. These motions act like an electrical dynamo and generate an electric current that produces a magnetic field. In Jupiter and Saturn, metallic hydrogen serves as the dynamo.

Uranus and Neptune are somehow different. With far more ice and far less hydrogen than Jupiter and Saturn, it is possible that the cores of Uranus and Neptune do not conduct electricity as well as the fluid layers halfway out to the surface do. An electrical dynamo still operates in these two planets, but *around* the planet's core rather than *in* the core. This could explain the offset of the magnetic field; complex interactions between planetary spin and fluid flow would then explain the tilt.

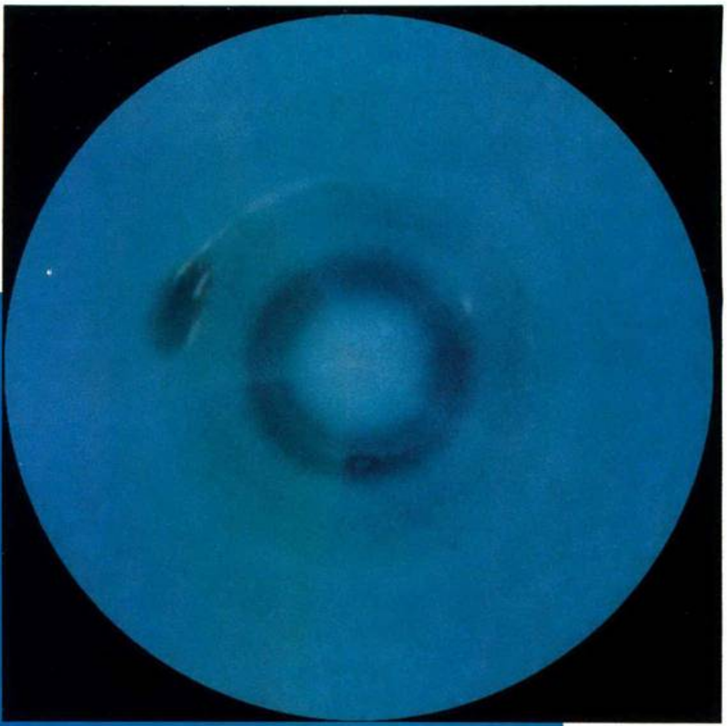
Preliminary results show that Neptune has the "emptiest" magnetosphere of any of the giant planets, that is, the density of charged particles speeding around in the magnetic field is lower than those on Uranus, Saturn, or Jupiter. The plasma detected in the magnetosphere contained ions of hydrogen, helium, and nitrogen. At least some of the ionized hydrogen and helium observed probably came from Neptune's upper atmosphere, but the nitrogen ions had to come from Triton's atmosphere.

Because the magnetic field is tilted so strongly and the source of heavy nitrogen ions — Triton — moves in and out of the magnetic field's equator, the magnetic field is twisted into a complex shape. Thus it will take many months of effort to disentangle the complex magnetic field structure that *Voyager* explored.

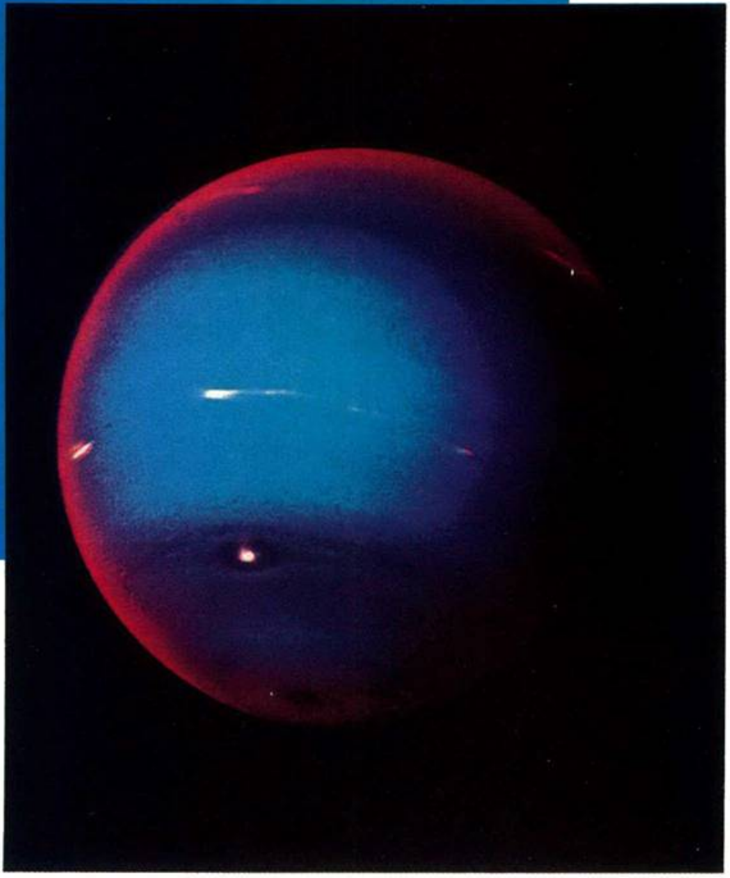
The existence of a magnetic field served a valuable secondary purpose for *Voyager*. As the spacecraft approached Neptune, its antennas began to pick up bursts of radio noise every sixteen hours, as regular as clockwork. Although the exact mechanism generating these radio signals was not clear, it was obvious that the signals originated from on or near Neptune, involved Neptune's magnetic field, and came in bursts every 16 hours and 3 minutes. Thus the signals, created in a spinning magnetic field and linked to the deep interior of the planet, revealed the long-sought rotational period of Neptune.

A different Neptunian vital statistic came from the radio tracking experiment. As *Voyager* accelerated toward Neptune, Earth-based antennas monitored the Doppler shift of the spacecraft's signals and used them to "weigh" Neptune. Ultimately, these measurements will yield a determination of the distribution of mass inside Neptune. A quick-look analysis of tracking data gives an overall density of 1.640 grams per cubic centimeter, making Neptune the densest of the giant planets. The density of Uranus is 1.267 grams per cubic centimeter.

These values will be used in the coming months and years as constraints on mathematical models of Neptune's interior. From dozens of vital statistics and seemingly small clues, planetary physicists will construct a



NEW VIEWS OF NEPTUNE
Above: From five images of the planet, *Voyager* scientists constructed an image of the southern hemisphere of Neptune. Below: Red denotes high-level haze in this false-color image. The red is strongest at the limb because we see the most haze there.



DENSE SEGMENTS shine brighter than the rest of Neptune's outermost ring, making Neptune's ring system difficult for astronomers to understand. In the midst of its brilliant glare, we see the crescent image of Neptune. The particles that make up the rings are blacker than coal dust.

detailed picture of the composition, density, and physical state of Neptune's interior.

Winds and Weather on Neptune

For a planet near the chilly outer edge of the solar system, Neptune is remarkably active. To the bafflement of *Voyager* meteorologists, Neptune maintains winds of at least 325 meters per second (700 miles per hour) that blow westward around the planet. Neptune produces these winds with one-twentieth of the solar energy that Jupiter has to power its weather.

On Earth, friction would soon rob such powerful winds of their energy. On Neptune, however, where the energy to overcome friction is simply not present, the winds must flow almost frictionlessly around the planet or they wouldn't blow at all. Understanding the physics of Neptune's wind will occupy planetologists for years to come.

Buried in the planetary wind system are several large vortices. The largest of these is the Great Dark Spot, or GDS, a whirlwind the size of Earth. It rotates counterclockwise with a period of about ten days. Inside this vast spinning mass, the hazy deck of methane stratus clouds that covers most of the planet is absent. The GDS is thus a hole in the clouds, through which we can look deeper into Neptune's atmosphere. All we see is a darker shade of Neptune's ubiquitous blue methane envelope.

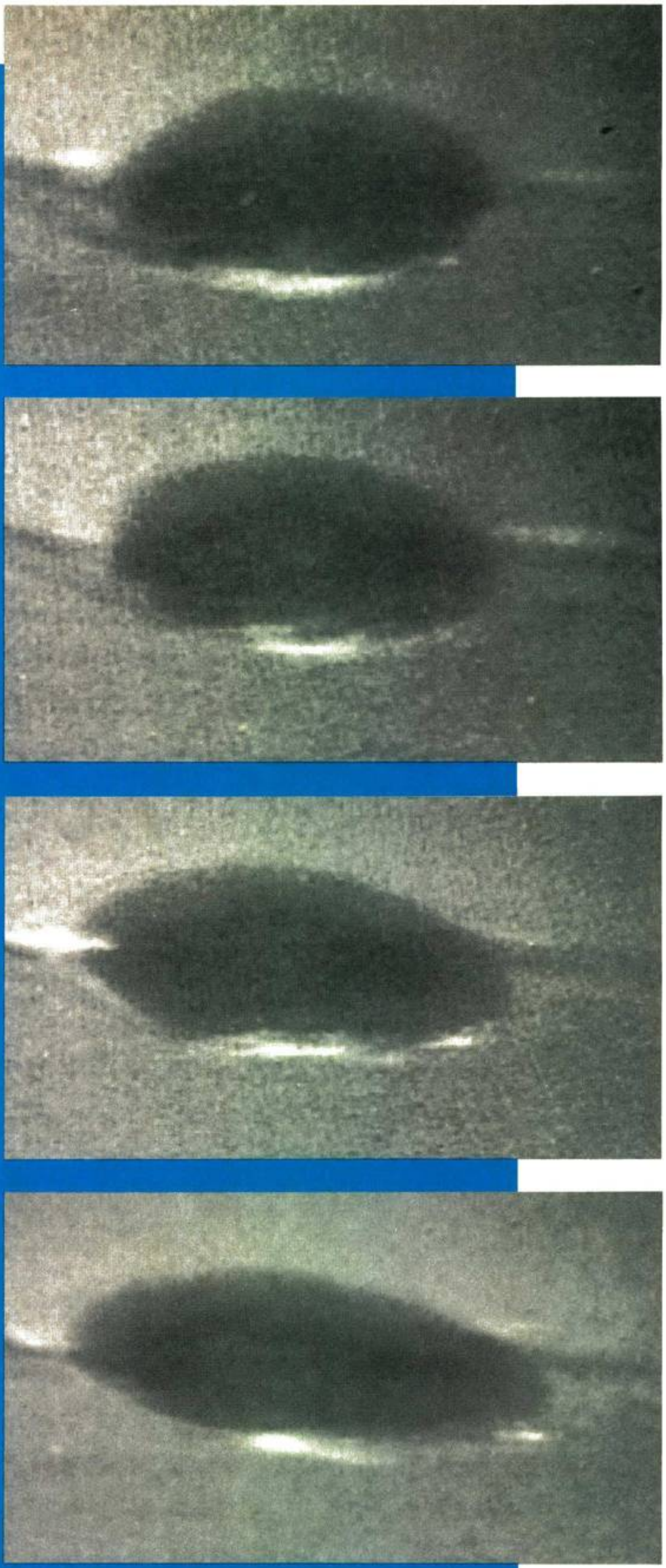
Fifty kilometers above this vast hole in the methane cloud deck, cirrus-like clouds form and dissipate. Like the clouds that form in the lee of terrestrial mountains, cirrus clouds form when methane-rich Neptunian air is forced over the vast pressure dome of the GDS; the air then cools and condenses to form clouds. So strong is its effect that cirrus forms halfway around the globe from the GDS, in the wake of this huge obstruction.

To the south, eye-shaped Dark Spot Two spins about a plume of rising methane-rich air that condenses to form the white clouds. Such plumes maintain the high concentration of methane observed in Neptune's stratosphere. Sunlight strikes methane molecules and breaks them apart; the fragments then recombine into heavier molecules — such as acetylene — that condense into droplets and fall out. The plumes carry heat from Neptune's interior and replenish Neptune's supply of stratospheric methane.

"Scooter" is a different type of plume. It comes from deeper in the atmosphere than Dark Spot Two's plume and does not rise as far. Because "Scooter" rotates at the same rate that the deep core of Neptune does, it may lie over a deep-seated hot spot and be convection from the hydrogen sulfide cloud layer below the methane cloud deck we see.

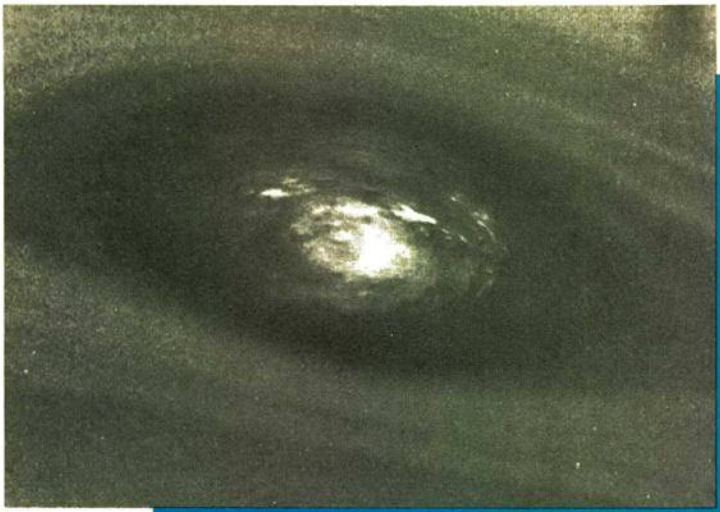
Rings and Moons

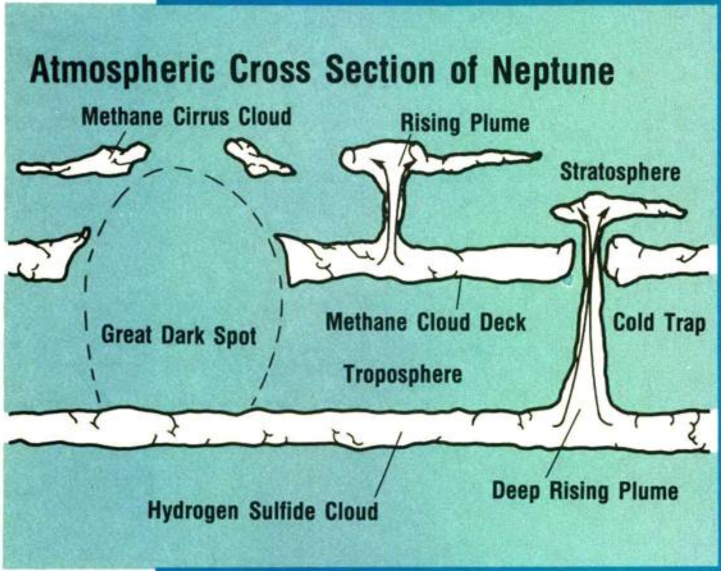
Orbiting Neptune is a system of rings and a dust sheet in the equatorial plane. The two brightest rings are very thin (only a few tens of kilometers in width), but they completely encircle the planet. They are called 1989 N1A and 1989 N2A. Two small "shepherd" satellites keep the ring particles tightly confined. Neptune's third ring is closer to the planet than the outer two, extremely diffuse, and some 2,500 kilometers (4,000



THE GREAT DARK SPOT
Counterclockwise rotation marks the Great Dark Spot as a high-pressure region in Neptune's atmosphere. Taken on four successive rotations of Neptune, these photos show the GDS changing shape. It starts short and thick and stretches out in the following frames.

DARKER EQUALS DEEPER on Neptune. The Great Dark Spot is a vast high-pressure region free of the tropospheric methane clouds that cover most of the planet. The spot is thus a clearing that lets us look deep into Neptune's atmosphere.





CLOUDS FROM THE DEEP
Clouds form in Neptune's atmosphere at three levels. The highest clouds are the cirrus-like streamers that girdle the planet. In Dark Spot Two, we see a rising plume of clouds from the methane cloud layer. In "Scooter," we may see a plume from the deep hydrogen sulfide cloud layer.

miles) broad. It was nicknamed the fuzzy ring. Finally, a broad thin disk of fine dust particles extends from midway between the outer two rings inward toward the planet. The edge of the dust sheet is a bit brighter than the rest and has been nicknamed "the plateau."

Neptune's outermost ring baffles astronomers who study rings. Embedded in the continuous ring are three bright ring segments — ring arcs — that contain far more material than the rest of the ring. One of the highest-resolution images of the ring arcs showed unresolved bright points of light embedded in the ring, like a parade of tiny moonlets each perhaps 10 kilometers (6 miles) or less in diameter. None of the other rings showed any sign of moonlets.

Embedded moonlets seemed to offer some hope of an explanation of why material in the dense ring segments might not spread around the entire ring, but the proposed theories did not last long. Observations looking back at Neptune from a high sun angle showed the arcs to be bright, as fine dust would appear, rather than dark, as the shadowed sides of moonlets would be.

The other rings are also rich in dust and glow brightly when viewed from high sun angles. All, that is, except the plateau ring. It is brighter in light scattered back toward the Sun, which implies that this particular section of the dust disk is made up of fairly large particles and relatively little dust.

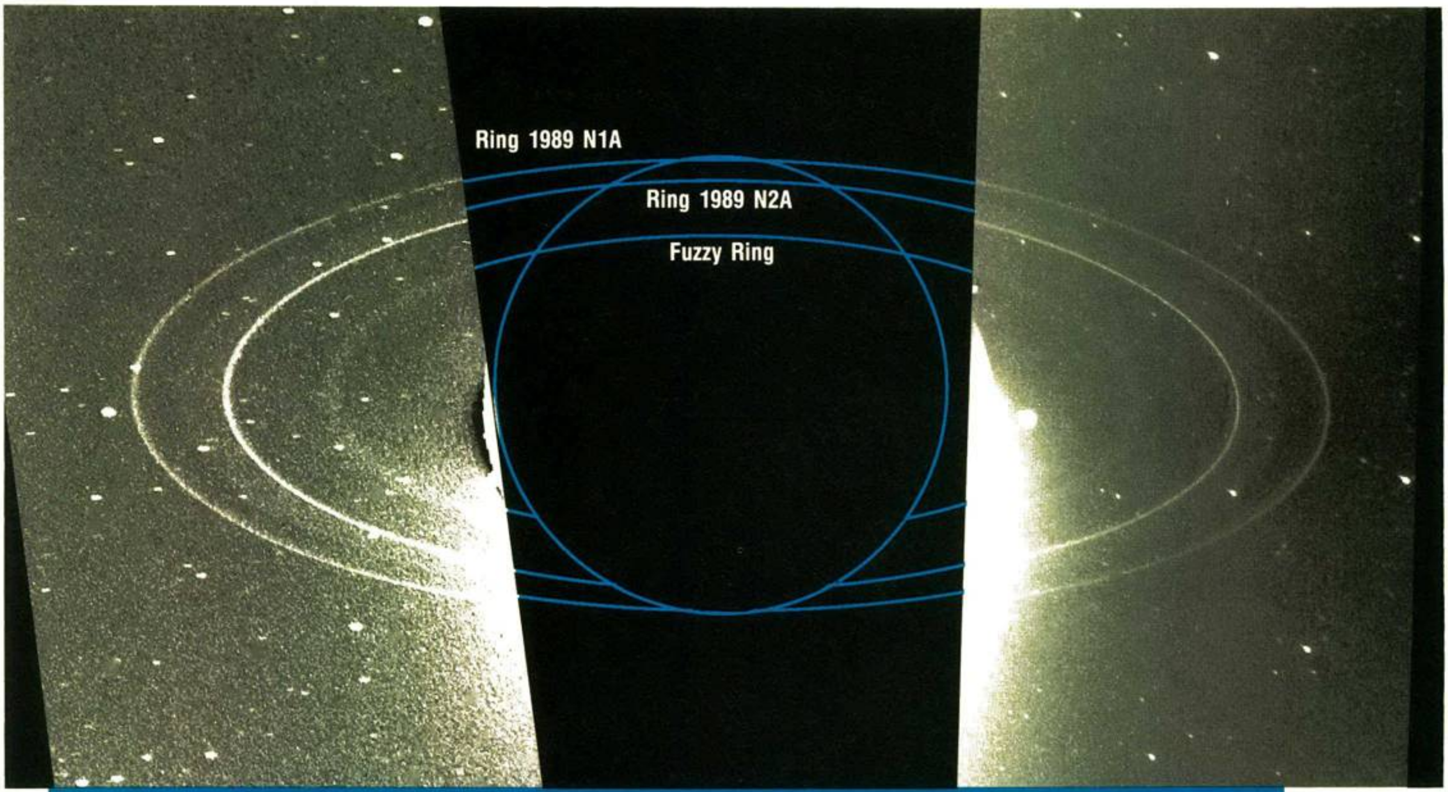
Despite the novelty seen in Neptune's ring system, planetary astronomers see many similarities between Neptune's rings and the rings of the other giant planets. *Voyager* observed dust sheets at Uranus and Jupiter. Saturn's F-ring and the "kinky" ring inside the Encke division show dense regions like those in the 1989 N1A ring. However, neither of the standard explanations —shepherding satellites and what ring researchers call co-rotation resonances — works to account for a ring like 1989 N1A.

Voyager raised the number of Neptunian satellites to eight and demoted Nereid (discovered in 1949) from second to third rank in order of size. At 400 kilometers (240 miles) in diameter, 1989 N1 is larger than Nereid, which is 340 kilometers (210 miles). If 1989 N1 orbited Neptune at a greater distance, it would have long since been discovered from Earth. *Voyager* imaged 1989 N1 and 1989 N2; both moons turn out to be nonspherical and heavily cratered. Furthermore, both reflect only about 6 percent of the sunlight that strikes them and thus are jet black.

Triton

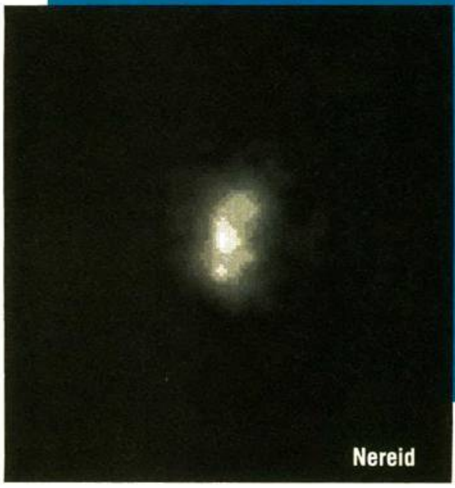
In many respects, the icy satellite Triton stole the show from Neptune. This satellite — just a bit smaller than Earth's Moon — has amazingly complex land forms and albedo markings. Yet the conventional scientific wisdom predicts that such a body should be frozen solid and basically unchanged since the origin of the solar system.

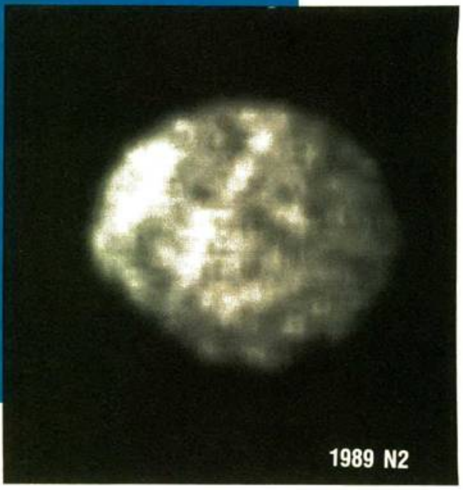
Even before the flyby, however, Triton was clearly a strange moon. It orbits Neptune in the retrograde sense, that is, in the direction opposite Neptune's spin. Furthermore, Triton's orbit is inclined to Neptune's equator. Both of these facts point toward a different sort of origin for Triton; for example, Triton may be a captured planetesimal, a lucky survivor from the era of planetary formation. Four-and-a-half billion years ago, when the solar system was forming, tens of thousands of Triton-like bodies built Neptune. Only Triton escaped.

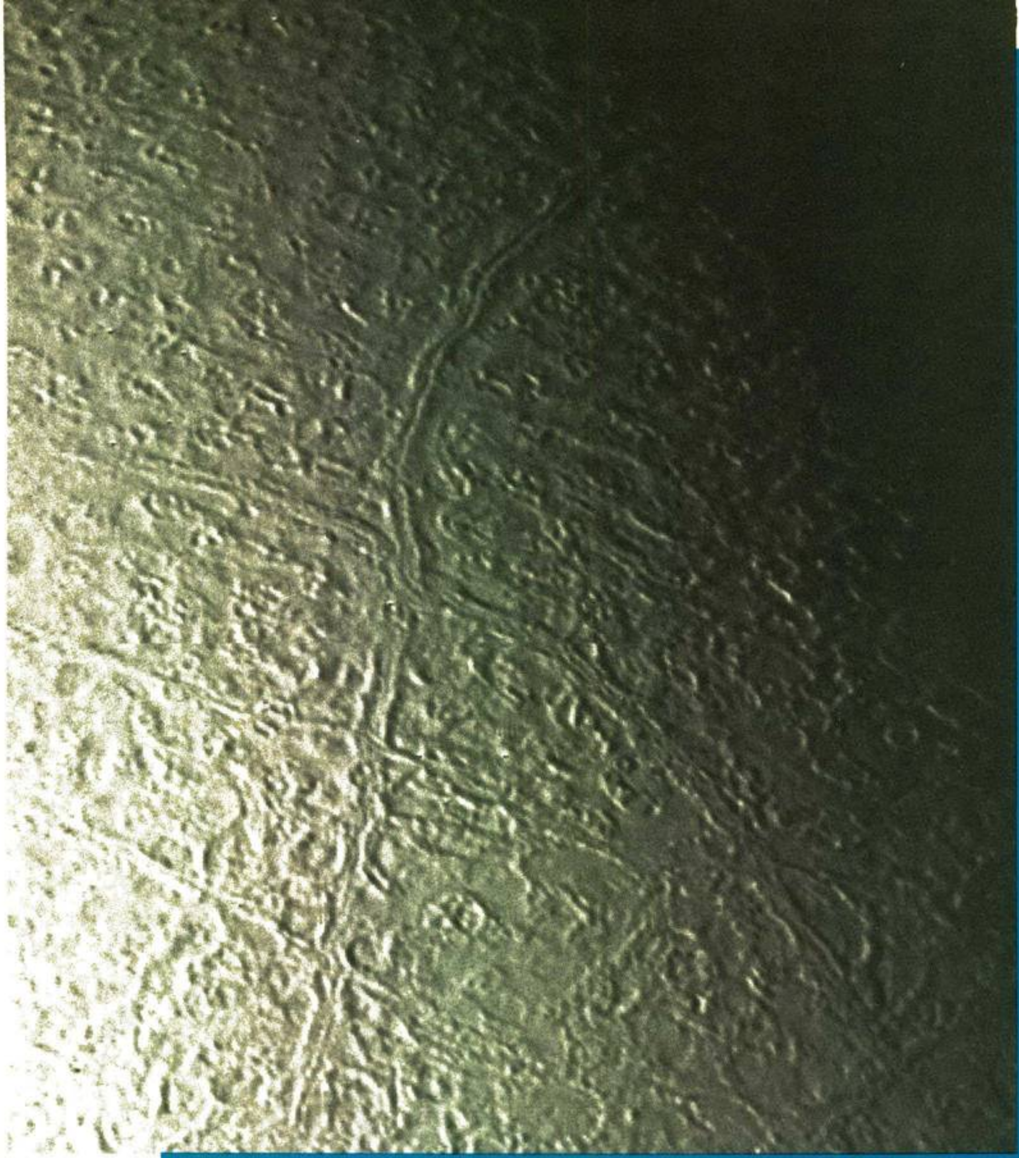

Ring 1989 N1A
Ring 1989 N2A
Fuzzy Ring

Neptune's Moons and Rings

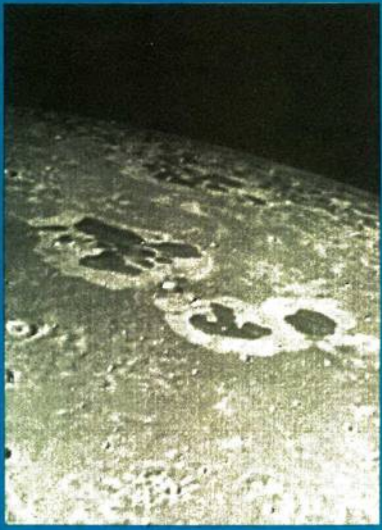
Name	Radius (Kilometers)	Dimension (Kilometers)	Description
Nereid	5,511,000	340	Eccentric Orbit
Triton	354,000	2,720	Retrograde Orbit
1989 N1	117,600	400	Equatorial
1989 N2	73,600	200	Equatorial
1989 N1R	63,000	17	Ring; Narrow, Dusty
1989 N4	62,000	160	Equatorial
Plateau	58,000	4,000	Disk; "Bouldery"
1989 N2R	53,000	17	Ring; Narrow, Dusty
1989 N3	52,500	140	Equatorial
1989 N5	50,000	90	Equatorial
1989 N6	48,200	50	Inclined 4.5 degrees
Fuzzy	42,000	2,500	Ring; Broad, Dusty







Cantaloupe Terrain



Dark Patches

TRITON'S SURFACE HAS A STORY TO TELL

Three styles of volcanic activity, a vast polar cap, strange "cantaloupe" terrain — what do these features mean? In all probability, they point to Triton's capture by Neptune; a long, complex history; and continuing activity on this cold body.

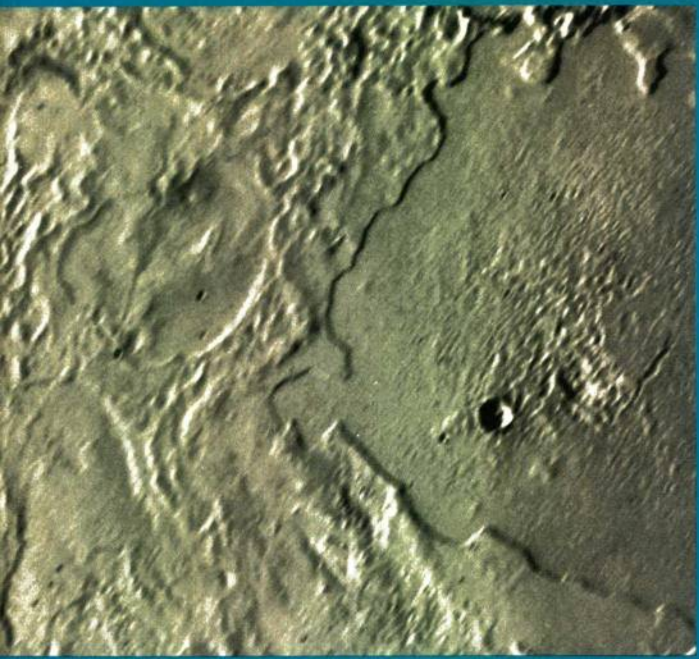
Voyager yielded Triton's vital statistics: its mass is 21.3×10^{21} kilograms and its diameter is 2,720 kilometers (1,700 miles). This means Triton has an average density of 2.03 grams per cubic centimeter, a little over twice the density of water. Therefore, Triton is made from a mixture of ice and rock, and not pure ice as some astronomers had expected. It also implies that Triton is a first-cousin to Pluto, similar in both size and density.

During *Voyager*'s approach to Triton, the spacecraft's cameras viewed the southern hemisphere and Triton's immense polar cap. This almost perfectly white, frozen nitrogen frost-cover extends from the south pole three-quarters of the way to Triton's equator and reflects much of the sunlight that falls on Triton back into space. Triton, therefore, is even colder than Pluto.

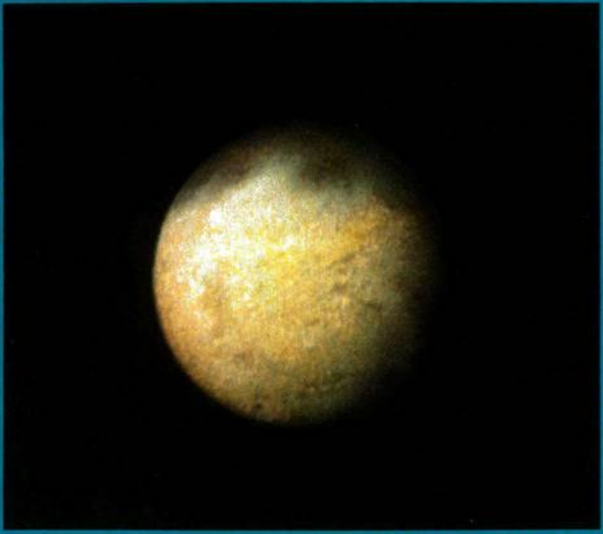
When *Voyager* flew by, it was summer in the southern hemisphere, and Triton's southern polar cap lay in full sunlight. Despite the extreme chill, the cap appeared to be evaporating and breaking up. Against the pure white of the nitrogen frost cap, even slightly darker areas would absorb more sunlight and heat rapidly. These dark areas in turn would melt and darken the frost nearby, creating "runaway" melt zones in the polar cap. However, the overall patterns in the cap defied quick scientific interpretation; often the imaging team could not distinguish between terrain and dark markings of the ground.

Clearly visible on the cap, however, were dozens of dark, feathery streaks all trending roughly northeast. One explanation is that the streaks result when pockets of liquid nitrogen below ground suddenly boil and discharge sun-darkened methane ice crystals into the cold, thin air. Carried by frigid winds moving across the polar cap, the dark streaks show that Triton is active and changing even today.

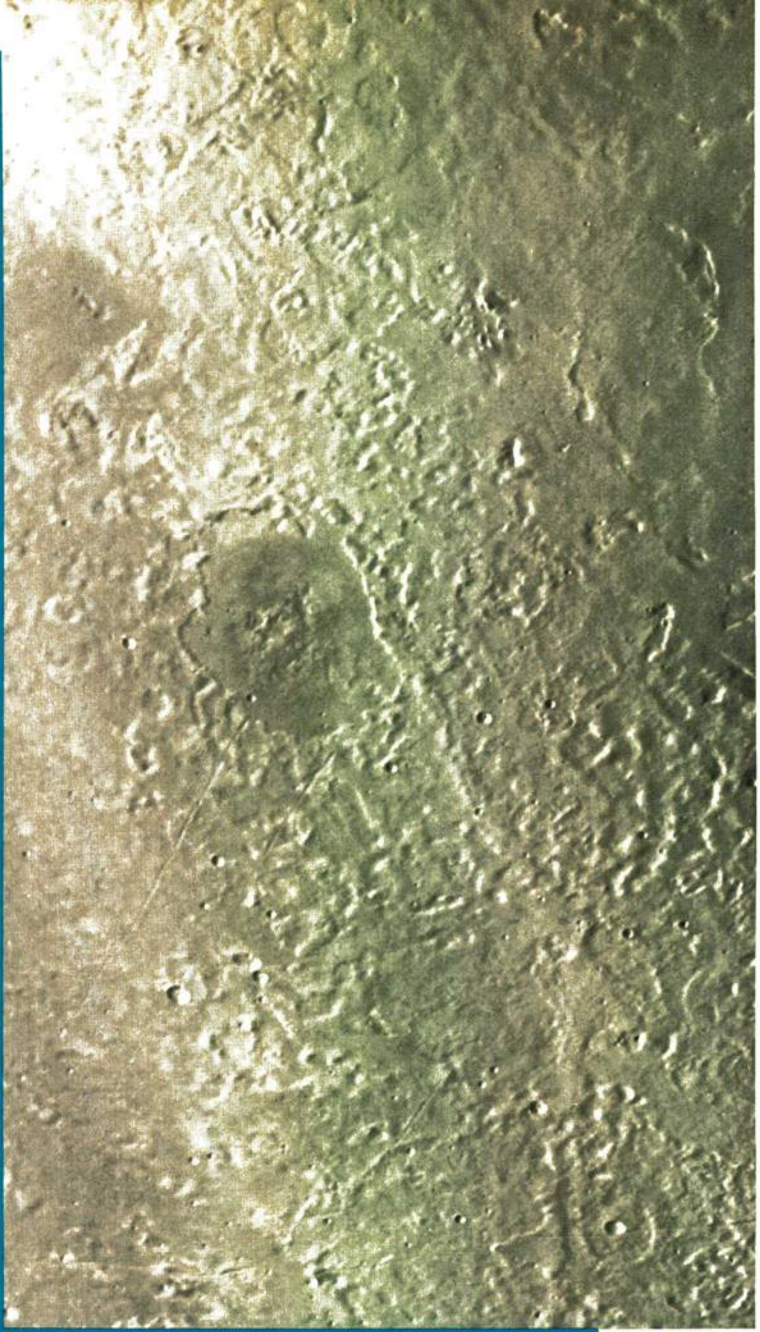
Polar cap melting may trigger these outbursts. On Triton, the pressure of ten meters of frost or snow cover is enough to melt nitrogen snow, producing pockets of



Lava Lake and Flow Features



Triton from the South



Rolling Terrain

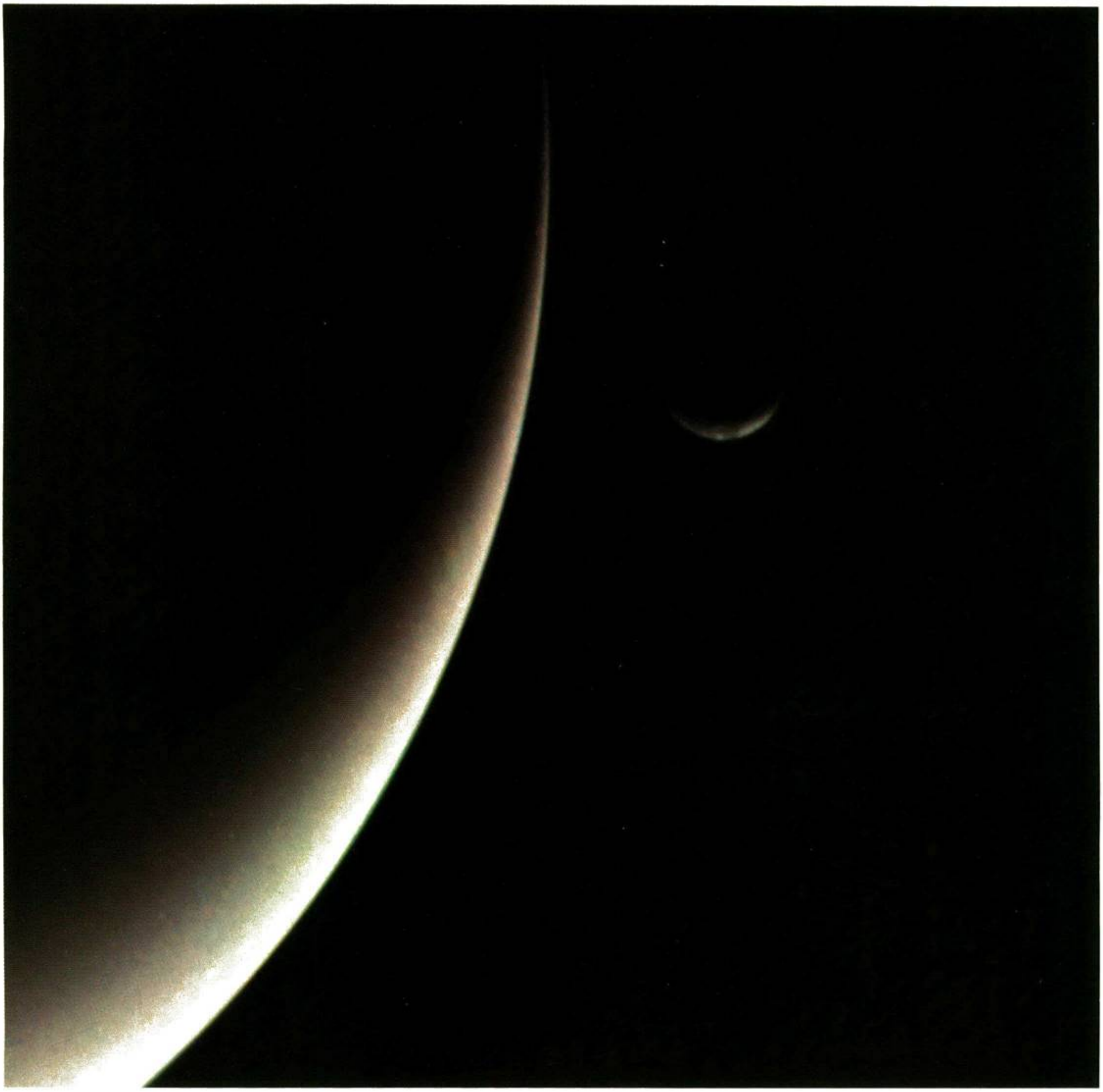
liquid nitrogen below ground. As southern summer advances, the polar cap warms and the snow pack evaporates, so the pressure on this underground liquid decreases. If a crack to the surface opens, the liquid nitrogen can flash into gas, just as the water in an overheated car radiator suddenly boils when the radiator cap is removed.

Much of Triton's equatorial zone consists of "cantaloupe terrain," low-relief polygonal ridges and valleys. Crossing the cantaloupe terrain in many places are long, thin ridges where, presumably, the crust of Triton split and a thick slush oozed out before freezing. This type of volcanism is similar to ridges along the valley floors on Uranus' satellite Ariel and reminiscent of the grooved terrains on icy Ganymede. Cantaloupe terrain may be yet another exotic form of icy volcanism — no one knows.

On the broad smooth plains of Triton, there is evidence of large-scale lava flooding. Thin lava flowed, retreated, and flowed again before freezing in the bitter cold. Some of these flows are ancient and show as many impact craters per unit area as the oldest lunar maria do. In other areas the flooding ice lavas look fresh and virtually crater-free. The numbers of craters on their surfaces suggest they could be anywhere in age from fairly recent to as old as 500 million years.

Triton's volcanism is "volcanic" with a difference. The "lavas" that flow from the interior and spread across the frozen plains or ooze from the interior are not molten rock as on Earth, but ordinary water mixed, perhaps, with ammonia and methane. Mixed ices flow at much lower temperatures than pure water ice does, and ammonia and methane should have been present as ices in the solar nebula where objects like Triton accumulated. Therefore, mixed ices are considerably more likely than pure water ice. Besides, at the frigid surface temperature of Triton, pure water ice is as hard as steel.

Detailed analysis of the images and careful consid-



THE CRESCENT OF TRITON emerged from behind the crescent of Neptune for *Voyager*'s cameras three days after closest approach. Neptune appears white in this picture because hazes in its atmosphere scatter all colors of light.

eration of the features and terrains of Triton will eventually fill in the details or replace the *Voyager* imaging team's working scenario of Triton's past. Four and some billion years ago, they propose, outer planets like Uranus and Neptune captured thousands of icy Triton-sized and smaller planetesimals and grew rapidly toward their present size. Two bodies escaped — Triton and Pluto — because their orbits by chance kept them from being gobbled up by Neptune.

At some time, however, the body that would become Triton ventured too close to Neptune. Whether gas drag or collisions with the original set of Neptunian moons slowed it so that it was captured we may never know, but Triton almost certainly began life as a moon in a long, elliptical orbit.

In this orbit Triton experienced severe tides, tides that flexed the tiny, icy body with every orbit and heated its core. Strained ice melted and flowed, erasing Triton's old cratered surface. From the cold-frozen interior volatile gases rose, and dense silicate minerals sank toward the core. As friction robbed energy form its orbit, Triton's innards erupted and flowed across the surface.

The Triton *Voyager* saw last August reflects that long history. In its twelve years of exploration and discovery, *Voyager* sent back pictures that expanded the known realm of the universe and the thinking of mankind. It is perhaps fitting, then, that what may be *Voyager*'s most fascinating satellite was also its last encounter. ☐

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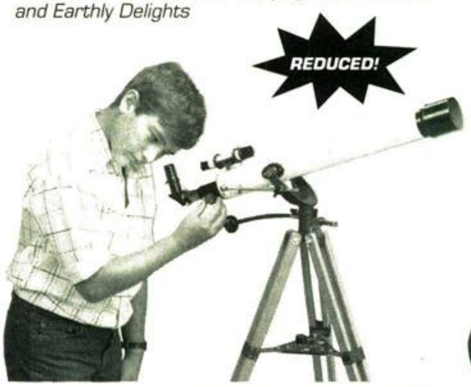

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8" Dew Zapper
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>
> *"Even in a metropolitan, light-polluted yard, I was able to enjoy several Messier objects in short order, aided by the setting circles. M13, the Hercules cluster, was appreciably brighter and more extended than in the 3" reflector, and was clearly a globular, not just a fuzzy smudge.*
>
> *"It was a pleasure to scan across M44, the Beehive cluster, with a decent Kellner eyepiece instead of suffering the tunnel vision of the usual inexpensive scopes. In all, a winner, and enjoyable to use, even for a seasoned observer."*

Only a specialty telescope company like Orion can offer such an affordable, high quality instrument as the Sky Explorer, worlds apart from the typical department store gadget with plastic tube and optics. At a modest price, you get virtually a home observatory: optical tube assembly, equatorial head with setting circles, adjustable tripod, 2 eyepieces, finderscope, eyepiece tray, and even a handy built in mini-light!

The Sky Explorer's optical system has a 900mm focal length, considerably longer than typical lower-power department store scopes. The sharp, clear 60mm objective doublet is magnesium fluoride coated for improved contrast and brightness. Not a plastic tube, but a sturdy white enameled aluminum assembly includes an integral dew cap and lens shade. For easy aiming, you get a 6x30 crosshair achromatic finderscope with adjustable dual-ring mounting bracket for perfect, stable collimation with the main scope.

The rack-and-pinion focuser features extra-fine tolerance machining for smooth operation, twin knobs for convenient left or right hand adjustment, and extra-long drawtube to provide wide focal range and compatibility with optional camera adapters, image correcting prisms, and other accessories. The fully-coated and optically-sharp right-angle star diagonal permits comfortable overhead viewing, and offers an upright mirror image.

By day you may change the equatorial mount simply to altazimuth (right-left, up-down) mode for easy terrestrial viewing. You'll enjoy whale or boat watching, scanning distant mountains, or studying birds and nature. The low power mode is perfect for most types of daytime viewing. At night, convert in seconds to equatorial tracking, and then use the smooth vernier flexible extension controls to easily track the skies.

Where the Sky Explorer really shines is in the inclusion of two outstanding, fully-coated .965" Kellner eyepieces: 25mm (36x) and 9mm (100x). Includes RA and DEC slow motion controls, plus dual flexible steel control cables on both axes (and optional motor drive may be added!). An adjustable counterweight and tube cradle assembly permits perfect balancing, and the hardwood tripod features a stabilizing platform for holding eyepieces (with nifty night light) and rubber tips that quickly dampen vibrations.

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Advanced multi-layer 'interference' filters block the most common undesirable light pollution, while passing other wavelengths with very little attenuation. They feature improved blocking of mercury vapor light, and higher transmission at the critical Hydrogen Alpha and Hydrogen Beta lines than competing models, including expensive 'premium' models. They also improve planetary images–particularly on Jupiter–especially in conjunction with another colored filter. Ideal for both visual observation and color or black and white photography.

1.25" Broadband Filter	#5660	**$66.50** (1.89)
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The Most Versatile Multi-Purpose Scope Available

Ideal for high performance terrestrial observation, excellent, highly compact astronomical telescope, and superb precision 1000mm f/11 telephoto lens.

Includes deluxe 45° erect image diagonal prism, erect-image 8x20 finder scope with adjustable mount, custom-fit carrying case, and built-in tripod block. Equipped for optional camera adapter, tele-extender, photographic filters, and more. Also includes a quality 30mm (33x) Kellner eyepiece, and is compatible with many optional higher-powered .965" eyepieces. Optional black rubber armoring protects the scope from bumps and jolts. Optional Multi-Coatings increase light transmission by 10%.

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Basic Set of 4 Filters 1.25"

This perfect primary filter set includes all the most important 1.25" filters: includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

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Deluxe Eyepiece Cases

Standard Case For Barlows, Eyepieces, Star Diagonals

Beautiful black case is fitted with grey die-cut foam, designed to hold up to 10 eyepieces plus barlow, with extra room for diagonal prism and other items. O.D. 8-1/2"x12-1/2"x3-1/8".

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Large Case for 2" Eyepieces & Larger Accessories

Designed with extra depth to hold several 2" and specialty wide-field eyepieces, a 2" star diagonal, up to nine 1.25" eyepieces, and various other accessories. An extra foam pad at the top and bottom of the case provide extra protection. Available with your choice of precut foam insert (pictured), or diced foam insert to custom-cut to suit your needs. O.D. 9-1/2"x13"x5-5/16".

Large Deluxe Case with Pre-cut Foam	#5916	**$29.95** (2.69)
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TRAILBLAZERS OF ASTRONOMY

THE LEGACY OF EDWIN HUBBLE

Our universe expanded in 1923 when American astronomer Edwin Hubble took a close look at "spiral nebulae."

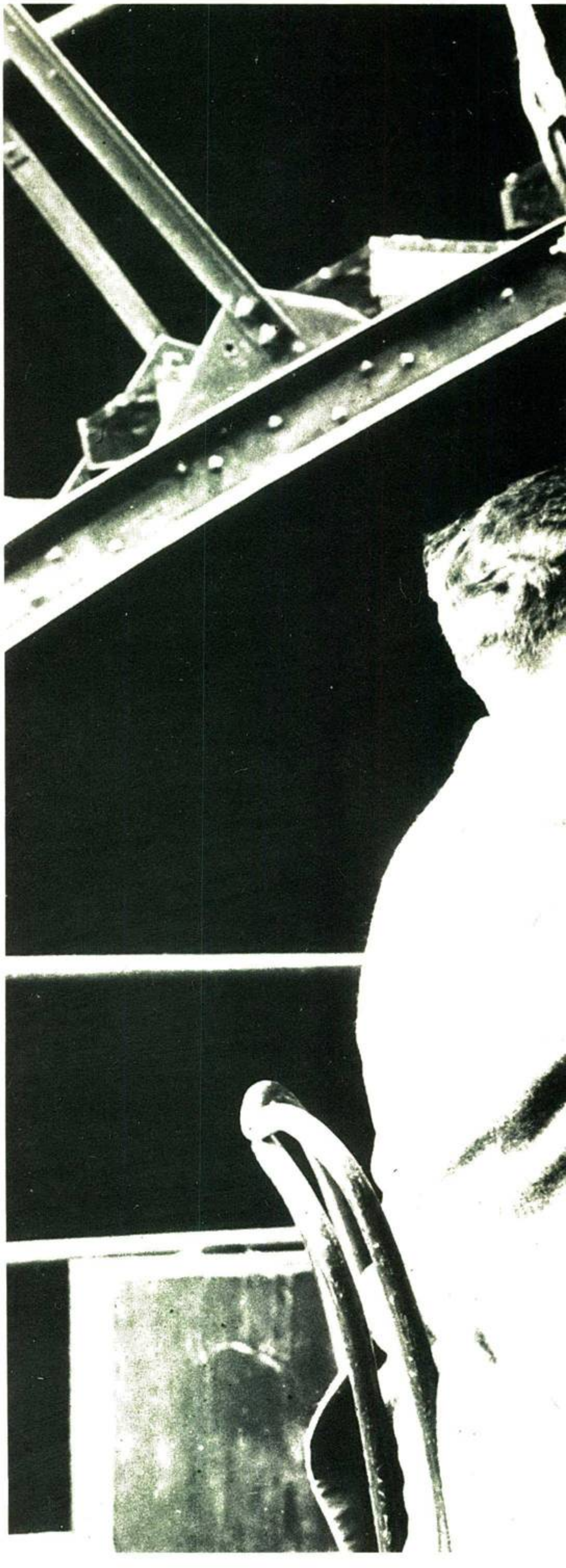
by Brian Jones

When the *Hubble Space Telescope* is launched in March 1990, it will carry with it the legacy of the man whose name it bears. No instrument could be more appropriately christened. The work Edwin Hubble began more than seventy years ago will come full circle when light from a distant galaxy falls upon the 2.4-meter mirror for the first time, and astronomers back on Earth search the image for clues to the depth and expansion of the universe.

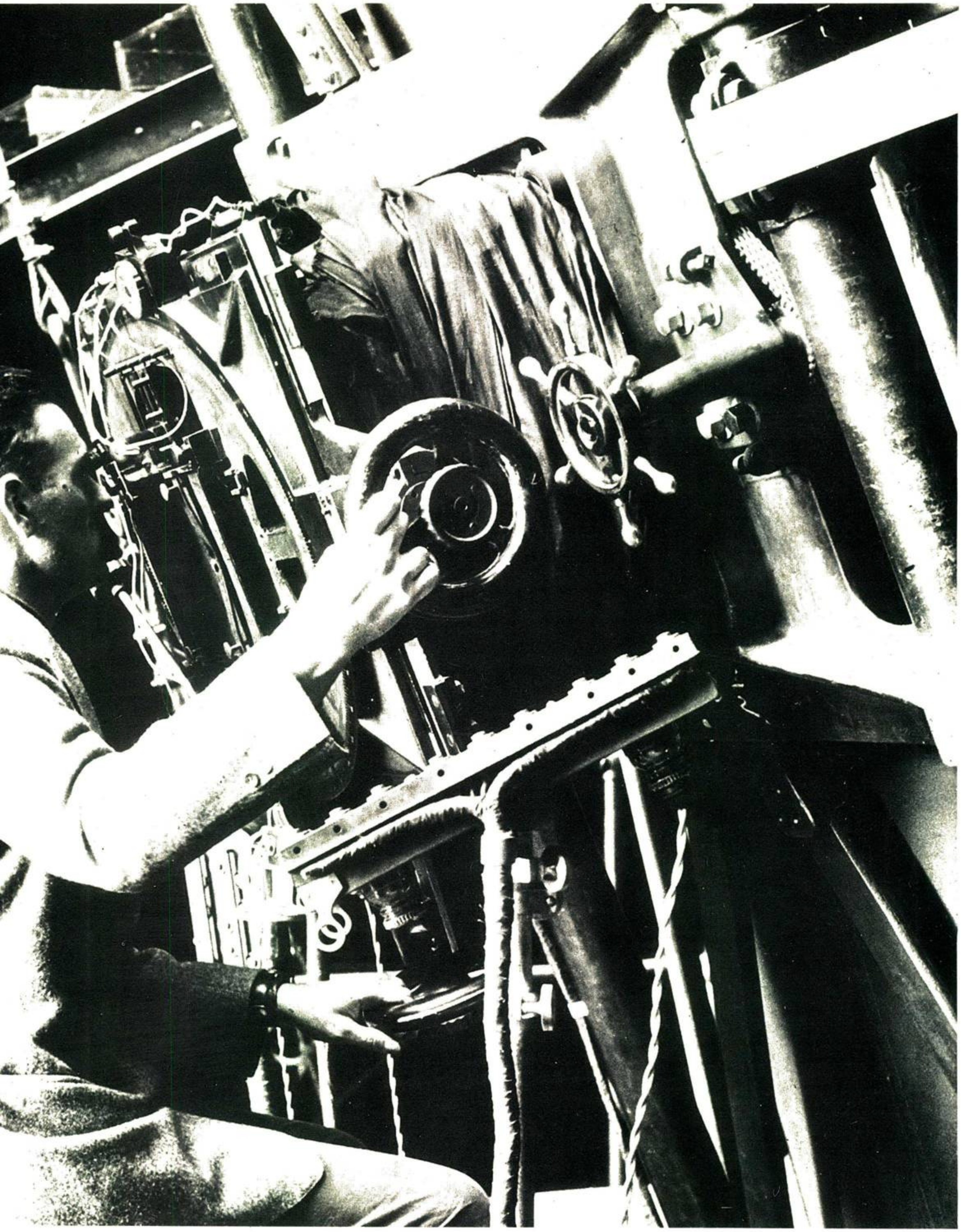
In a tribute to Hubble, American astronomer Nicholas Mayhall wrote: "It is tempting to think that Hubble may have been to the observable region of the universe what the Herschels were to the Milky Way system, and what Galileo was to the solar system. Whatever history's judgment, there is little doubt that Edwin Hubble was a master mariner in his 'realm of the nebulae'."

The story of Hubble's life is one of inquiry and fulfillment, of trial and judgement. Hubble was a man who was truly at home in the universe that was his life's passion and work. Although he entered astronomy in a roundabout fashion — in fact, he nearly went into law instead — his interest blossomed into a career that over a period of thirty years established the foundations of modern cosmology. It is interesting to consider that at the beginning of the twentieth century, astronomy had no clear idea of the size or scale of the galaxies, but by the time Hubble had been at work for a decade, the universe was transfigured and observational astronomy was redirected along new and daring paths.

Edwin Powell Hubble was born on November 20, 1889, in Marshfield, Missouri, the son of John Powell and Virginia Lee James Hubble. His father was a lawyer, and Edwin at first seemed set to follow the same professional path. His early years were spent in Kentucky and he attended high school in Chicago, where he won a scholarship to the University of Chicago. Although Edwin had been interested in astronomy as a child, it was while he was at the university that this interest was stimulated. This was probably due in part to the fact that there were several notable research physicists and astronomers at the University of Chicago, including



EDWIN HUBBLE at the focus of the 100-inch telescope at Mount Wilson in 1924.



Robert A. Millikan and George Ellery Hale.

In 1910 Hubble received his Bachelor of Science degree in mathematics and astronomy from the University of Chicago. Despite his astronomical interests, however, he stuck to his plan to take up a career in law and spent the next two years studying jurisprudence as a Rhodes Scholar at Queen's College, Oxford. After receiving his Bachelor of Arts and Jurisprudence degree, he remained at Oxford for one year as a lecturer.

In 1913 Hubble returned to the United States and, having been admitted to the bar, opened up a law office in Louisville, Kentucky. He halfheartedly practiced law there for a year until his deep-seated love of astronomy drove him to pursue research astronomy at the University of Chicago's Yerkes Observatory. Here, as a graduate student, he assisted stellar spectroscopist Edwin B. Frost, eventually gaining his Ph.D. in 1917 for his thesis "Photographic Investigations of Faint Nebulae."

In his thesis Hubble considered the classification of different types of nebula and stated that planetary nebulae probably existed within our own spiral system; however, spiral nebulae, as galaxies were then referred to, were "island universes" that lay beyond our Galaxy. Interestingly, Hubble noted that the identity and location of these extragalactic systems could be determined only by future astronomers using more powerful instruments.

Into the Realm of the Nebulae

It was during a visit to Yerkes Observatory in 1917 that George Ellery Hale, impressed by Hubble's observing skills, offered him a post at Mount Wilson Observatory, where the 60-inch reflector was in operation. Before Hubble could take the post, however, the United States entered World War I. Hubble decided to enlist as a private in the infantry, and he had to work particularly hard to finish his doctoral thesis before going overseas. Hubble telegraphed Hale: "Regret cannot accept your invitation to join the Mount Wilson staff. Joined the army instead. Am off to war."

After serving in France, Hubble remained a member of the American occupation force in Germany for an additional year following the armistice and achieved the rank of major. Afterwards, he took up Hale's offer and joined the Mount Wilson staff in autumn 1919.

Hubble's initial efforts at Mount Wilson were directed towards a general study of galactic nebulae (what we today refer to as gaseous or diffuse nebulae) and non-galactic nebulae (discrete "nebulae" located outside our Galaxy — in other words, galaxies). In one of his early papers, Hubble devised a classification system for these objects based upon differences between galactic and non-galactic nebulae.

An important part of Hubble's results concerned the source of luminosity in diffuse galactic nebulae. He concluded that the gas within these nebulae was made luminous by the radiation of associated stars. The gas and dust within the clouds were not themselves hot enough to shine, but became visible through the radiation of stars either within or close to the nebulae. In a subsequent paper Hubble showed that very hot blue stars in or close to the nebulosity excited the gases to fluoresce; furthermore, there was a relationship between the magnitudes of these stars and the luminosity of the associated nebulosity.

In 1919 Mount Wilson's 100-inch telescope came into operation. This occurred at about the same time that Hubble began to turn his attentions to the study of spiral nebulae. One of his first lines of investigation was the "condensations" observed in large spiral nebulae. In 1910 G. W. Ritchey, who was to become one of the foremost astronomical opticians, had obtained a series of photographs of a dozen spirals with the 60-inch reflector on Mount Wilson. Each photograph, he pointed out, contained a number of tiny, spherical condensations. He called these condensations "nebulous stars" and argued that they were stars in formation.

At the time, the island universe theory had two versions. One version was that other star systems of various sizes existed beyond our own Galaxy. The other, often referred to as the "comparable galaxy theory," stated that the external systems were similar in size to our own. If the condensations Ritchey observed were stars in the making, it appeared that the spiral nebulae were in the process of forming young clusters of stars. This being the case, the spirals could not contain enough material to be similar in size to our own Galaxy, thereby going against the comparable galaxy theory.

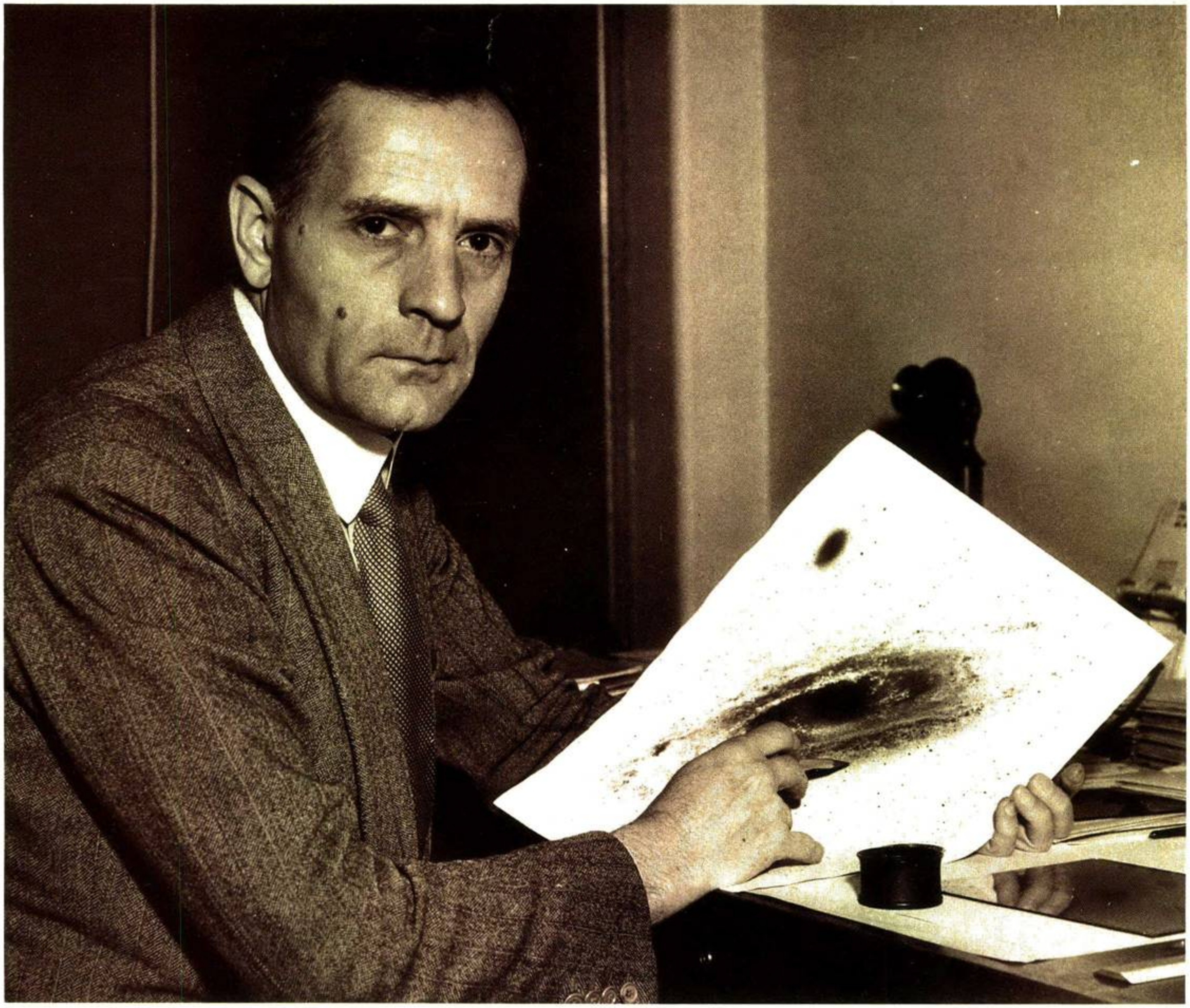
Hubble observed these nebulous stars with the 100-inch reflector and obtained photographs that produced images of the condensations that had the smallest angular diameters hitherto recorded. Hubble was almost certain that the objects actually *were* stars, although he felt more evidence was required to settle the matter.

One of the systems to come under Hubble's scrutiny was M87, and in a letter to astronomer Harlow Shapley July 5, 1922, he stated: "My own preference concerning the objects clustering about M87 is to call them stars until they may be definitely shown not to be stars. I believe they are stars but would not care to argue the point or to use this conclusion as a basis for speculation until better plates have been obtained. The stars begin where the nebulosity stops. I do not know whether this is a real or a photographic effect. . . . M49 shows a similar but less conspicuous clustering and there is some slight evidence of clustering about M60 . . . I have been calling objects of this class 'globular nebulae' because the term describes their appearance. The clustering effect around M87 had no bearing on the choice of a name. There should be no confusion. Globular clusters and globular nebulae signify similar forms of different sorts of object." Today, we know that these condensations around M87 are, in fact, globular clusters.

The Debate Heats Up

In April 1920 the issue over the nature of "spiral nebulae" culminated in the famous Shapley-Curtis debate, held at the National Academy of Sciences. Shapley was of the opinion that spiral nebulae were nebulous objects in our Galaxy, while Heber Curtis firmly believed that the spirals were "island universes," galaxies like our own existing in a universe that extended for tens of millions of light-years.

Much of the argument for Shapley's views came from measurements made by Adrian van Maanen, which indicated that M101, M33, and M81 were rotating 0.02 arcseconds per year. These large angular velocities suggested that these systems were only several thousand light-years distant, rather than lying beyond our own galactic system. (Examination of van Maanen's measurements by Hubble in 1935 showed that the apparent motions of these systems were erroneous. The motions arose from systematic observational errors, not through actual rotational motions.)



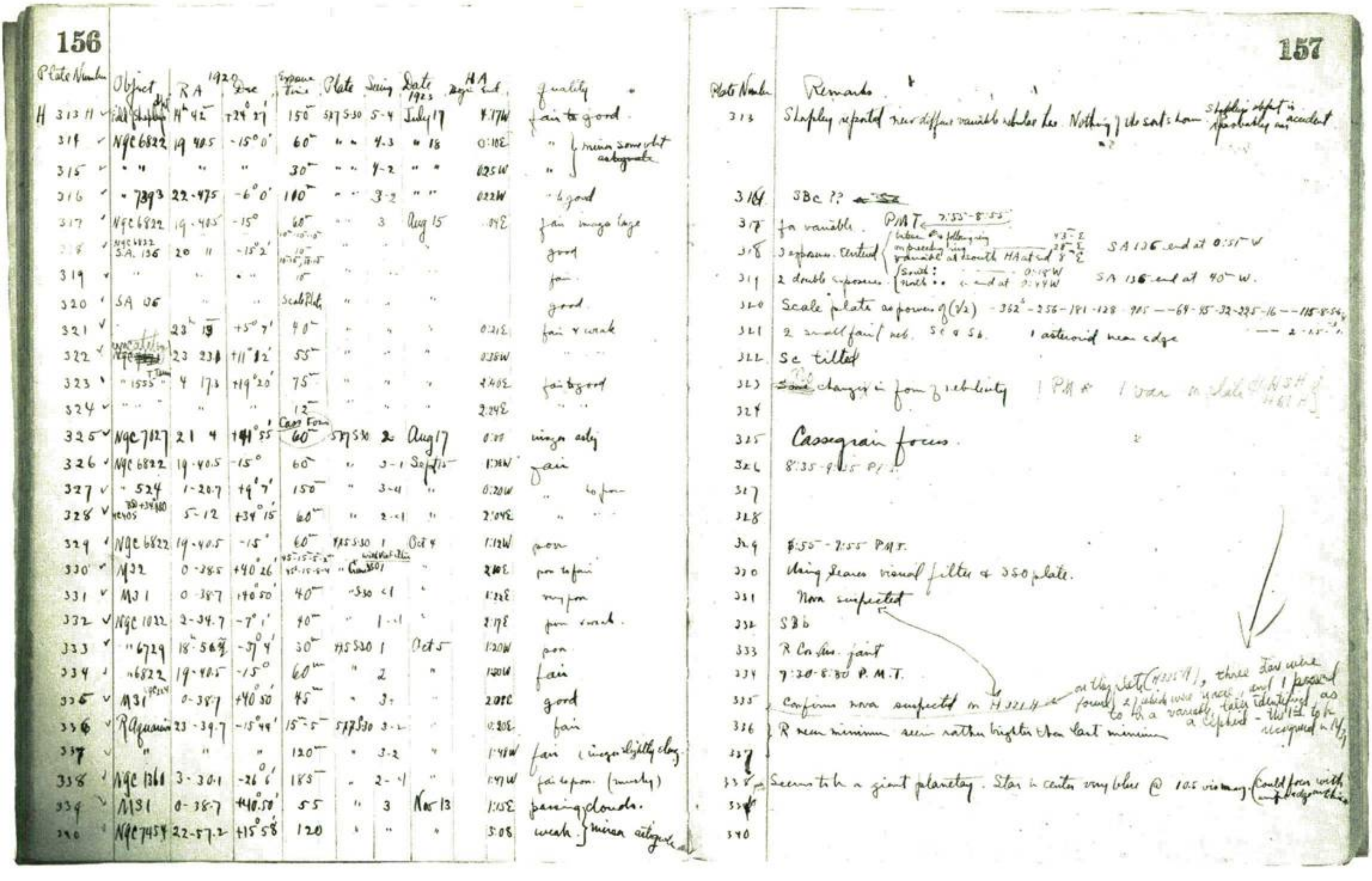
DISCOVERY AND DISCOVERER, Hubble displays the historic October 1923 plate in which the first Cepheid variable in M31 was detected.

Hubble, meanwhile, continued to look for conclusive evidence that would either establish or repudiate non-galactic nebulae as extragalactic in nature. One object that particularly attracted his attention was NGC 6822, an irregular galaxy in Sagittarius discovered by the great observer E. E. Barnard in 1886. Hubble's interest in NGC 6822 stemmed from its resemblance to the Magellanic Clouds, although it was much smaller than even the Small Magellanic Cloud. (In fact, NGC 6822 is a member of the Local Group of galaxies.) In his letter to Harlow Shapley dated July 23, 1923, Hubble referred to NGC 6822 as "our pet Magellanic Cloud."

In the same letter to Shapley, Hubble stated: "I got [John C.] Duncan to take it with the 100-inch July 5, 1921, and have suspected the probable nature of the object ever since but have only just now got around to studying it. Plates collected this past month show the irregular cloud of faint stars, of which five are established as variables, four patches of diffuse nebulosity, all with emission spectra, and at least three planetaries. The similarity is thus established at every point. I propose to get some notion of magnitudes and color indices, hunt for more variables and investigate their periods and light curves, and attempt to get radial velocities from the brightest nebulae."

A series of photographs of NGC 6822 taken through the Mount Wilson reflectors revealed numerous different types of objects, including fifteen variables. Eleven of these variables were found to be Cepheids, an important class of yellow-giant stars that display regular brightness variations over a period of days.

Cepheids, it had been suggested over a decade earlier, could be used as distance indicators if the period-luminosity relationship discovered by Henrietta Leavitt of the Harvard College Observatory in the early 1900s could be properly calibrated. Leavitt, who studied Cepheids in the Small Magellanic Cloud, had noted that



the longer the Cepheid's period, the higher its luminosity. Thus, from a calibrated period-luminosity relationship, the Cepheids' absolute magnitude could be determined, and comparing the absolute magnitude with the apparent magnitude would yield a distance estimate.

From Leavitt's work, events began unfolding rather quickly. In 1913 the Danish stellar astronomer Ejnar Hertzsprung identified Leavitt's light curves of the Magellanic Cepheids with those of Cepheids in our Galaxy. Three years later Harlow Shapley calibrated the light curve and used it to determine the sizes and distances of globular clusters in our Galaxy that harbored Cepheids. This work provided the first accurate picture of the size and shape of our Galaxy.

This groundwork paved the way for Hubble to calculate the distance to NGC 6822 using Cepheids. His estimate came to around 700,000 light-years, which was by far the greatest distance measured for any object at the time. Harlow Shapley, who had been studying NGC 6822 at the same time as Hubble, confirmed this distance by making his own measurements. Shapley assumed the Magellanic Clouds and NGC 6822 were similar in nature and compared the brightnesses of various features within each object, including individual bright stars and nebulae. Using this method, Shapley arrived at a value of almost a million light-years for NGC 6822, a distance that compared favorably with the value obtained by Hubble using the Cepheid measurements.

A Cepheid in M31

Suddenly, the universe was much bigger than anyone had thought. This shocking conclusion was only beginning to sink in when, in February 1924, Hubble discovered a Cepheid variable in one of the outer spiral arms of the Andromeda "Nebula," M31. Hubble was studying a photographic plate of the "nebula" taken on October 6, 1923, when he located what he first assumed to be a nova. When he formulated a light curve for the object, however, it revealed the star to be a Cepheid. His observing notes, scrawled in a corner of his notebook, stated: "On this plate, three stars were found, 2 of which were novae, and 1 proved to be a variable, later identified as a Cepheid — the 1st to be recognized in M31."

In a letter dated February 19, 1924, Hubble informed Shapley that, "I have found a Cepheid variable in the Andromeda Nebula (M31). I have followed the nebula this season as closely as the weather permitted and in the last five months have netted nine novae and two variables. The two variables were found last week. No. 1 is roughly 16′ preceding the nucleus, but well within the borders of the arms, and is situated on a background of faint mottled nebulosity. Magnitudes were estimated rather hastily from a set of comparison stars and a light curve was constructed covering all available observations from 1909 down to date. The second variable is about 15′ from the nucleus just at the edge of the spiral arms, among the masses of stellar condensation. It is about half-a-magnitude fainter than the first and too faint for a reliable determination of the period from the data on hand. The most plausible figure at present is about twenty-one days, which fits excel-

A CRUCIAL PAGE from Hubble's logbook (opposite page) with his note in the lower right citing discovery of the Cepheid in M31. It reads: "On this plate, three stars were found, 2 of which were novae, and 1 proved to be a variable, later identified as a Cepheid — the 1st to be recognized in M31." The variable's location is indicated in the photo of M31 above.

lently well with the first, so well in fact that I will be skeptical of the figure until it is carefully checked."

By deriving the star's period of variability and assuming that all Cepheids with similar periods have equal absolute magnitudes, Hubble estimated that M31 was 900,000 light-years distant. This was the first positive indication that star systems — galaxies — existed beyond the confines of our own Galaxy.

Hubble followed up this initial discovery with further observations and, in all, discovered a total of thirty-six variables in M31, twelve of which were Cepheids. Hubble also found twenty-two Cepheids in M33, which enabled him to derive a distance estimate for M33 similar to the one for M31.

The "Great Debate" was over. The December 1924 announcement of Hubble's discovery was made at a joint meeting of the American Astronomical Society and the American Association for the Advancement of Science in Washington, D.C. (in the presence of Shapley and Curtis). Henry Norris Russell read the paper on Hubble's behalf.

In making his distance estimate, Hubble had assumed that all Cepheids had the same period-luminosity relation and that the light from these stars had not been absorbed by dust within either of these systems. Both assumptions were wrong, however. It was later found that there are different types of Cepheids and that intervening dust does dim their light. Nonetheless, Hubble's results ushered in a new era in cosmology.

Up to Hubble's time, cosmology had been an area explored mainly by theoreticians. Hubble, however, brought about a major change in how cosmology is done. From now on the universe beyond our own Galaxy would be explored observationally, including the study of both the distribution and motions of galaxies and galactic make-up and structure.

Hubble believed the galaxies to be the building blocks of the universe. Using both the 60-inch and 100-inch reflectors at Mount Wilson, he carried out a photographic survey of roughly three-quarters of the entire northern sky. His examination of the photographic plates revealed that galaxies were distributed fairly uniformly across the sky (allowing for the obscuring effects of our own Galaxy).

His study of galaxy distribution led him to the conclusion that the lack of galaxies along the main plane of the Milky Way was due to a layer of obscuring material in the galactic plane. Looking deeper into the sky, he found the rate of increase in the numbers of galaxies to be uniform. Having taken the effect of obscuration along the galactic plane into account, the overall distribution of galaxies he found strengthened his argument that these huge systems formed the framework of the universe.

Coincidental with this work, Hubble, in 1925, introduced a classification system of galaxy shapes consisting of two main categories: ellipticals and spirals. Each of these categories branch off into various subcategories based on galaxy structure. This system, though revised and refined by modern astronomers, is still in use today.

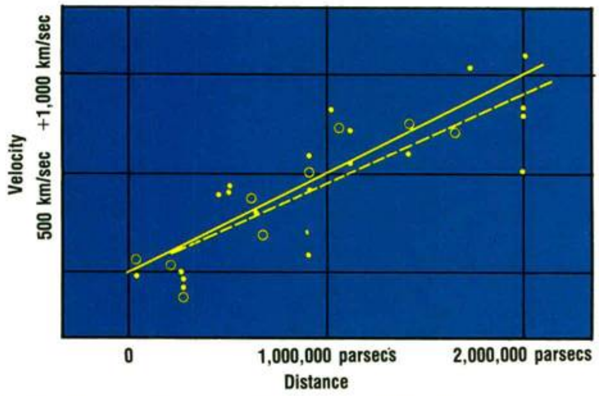
Building a Distance Ladder

By the mid-1920s, Hubble was deeply involved in galaxy research. In particular, he studied objects found in galaxies — globular clusters, emission nebulae, novae, variables, and bright stars — in order to construct a "distance ladder" out to ever more-distant galaxies. His assumption was that these objects would become increasingly fainter the deeper he probed into the universe. For galaxies beyond the Local Group, he planned to use the brightest stars as standard candles. But for more distant galaxies, he would have to resort to the average brightness of the galaxies themselves.

From the observational evidence he obtained, Hubble surmised that the brightest stars were on the order of 50,000 times as luminous as the Sun. Using the relationship between their apparent and actual brightnesses, he extended the scale of the universe out to about 6 million light-years. He realized all along that he couldn't be absolutely certain that the highly luminous objects he was studying and using for his estimations were actually stars (a fact borne out by subsequent observation, which revealed them to be bright ionized hydrogen clouds), although he did consider it safe to regard them as being comparable objects.

Hubble proceeded to extend the distance scale still further by observing clusters of galaxies. Just as the apparent luminosities of stars of known brightness had been used on a comparative basis for the nearby galaxies, the brightest galaxies in a cluster could be used to evaluate the distances of the most remote systems. Hubble based his estimations on the assumption that the average luminosity of the ten brightest members would be similar for every galaxy cluster. By drawing comparisons between different clusters, he extended the distance scale to 250 million light-years.

The Velocity-Distance Relation



HUBBLE'S PLOT OF VELOCITY AND DISTANCE for thirty-two galaxies out to the Virgo Cluster showed that the farther away a galaxy lies, the faster it recedes.

The Universe Unfolds

Truly, the universe was bigger than astronomers had believed or, indeed, imagined. If the vast dimensions radically changed astronomers' opinions about the size of the universe, Hubble's next discovery — that galaxies were all rushing away from one another — revolutionized cosmological thought.

The seeds of this discovery were planted in 1912 when Lowell Observatory astronomer Vesto Melvin Slipher made the first measurement of the radial velocity of a galaxy by studying the Doppler shift in the spectral lines of the Andromeda "Nebula." The Andromeda "Nebula" was found to be approaching Earth at about 125 miles per second. This, however, turned out to be an exception.

Over the next seventeen years, Slipher obtained spectra of an additional forty-six galaxies. He began to notice early on that their spectral lines were shifted from their "at-rest" position towards the red, or long, wavelength end of the spectrum. This indicated that the galaxies in question were receding from Earth. Heber Curtis, in fact, used this finding to support his argument that objects within our own Galaxy could not behave in this way.

During the mid-1920s Hubble and his colleague Milton Humason studied Slipher's galaxy spectra. Applying his range of distance indicators out to 6 million light-years, Hubble discovered that the more distant galaxies had higher recessional velocities. Moreover, their velocities seemed to be dependent upon their distance. Plotting the relationship between distance and velocity, Hubble obtained an approximately straight line, which indicated an increase in recessional velocity of around 100 miles per second for each million light-years of distance (in up-to-date terms, 500 kilometers per second per megaparsec). This relationship between distance and recessional velocity became known as Hubble's law.

Any advance in this relationship had to wait until observational data was available for more distant galaxies. This came about through the efforts of Milton Humason who, using a new type of fast lens, captured photographically the extremely faint spectra of remote galactic systems.

By 1934 the velocities of over one hundred systems had been measured. The relationship drawn up by Hubble was found to be true out to distances of 100 million light-years or more. The idea of a vast, static universe was replaced by a vast, *expanding* universe.

Although Hubble had firmly put the spiral nebulae in their place, well beyond the confines of our galactic system, it was clear to Hubble that a correction of the distance scale was necessary. In the early 1950s, Walter Baade discovered that there were two types of stellar populations in M31 and announced that Cepheid variables occurred in both Population I (young and luminous) and Population II (old and red) stars.

Research by Baade revealed that Population I Cepheids were roughly 1½ magnitudes brighter than their Population II counterparts, resulting in an error in the use of the period-luminosity law that Hubble had used to estimate the distance to M31. Hubble had derived his data from observations of the more luminous type 1 Cepheids. This resulted in a revision of M31's distance estimate; it was now twice as far away as before. This explained why the globular clusters around M31 were about 1½ magnitudes fainter than those in our Galaxy.

Hubble again diverted his attentions from astronomy with the entry of the United States into World War II in 1941. Although his age prevented him from applying for active service, he was appointed chief of ballistics and director of the Supersonic Wind Tunnel Laboratory at the Aberdeen Proving Ground in Maryland.

When the 200-inch reflector became available for observations in 1949, Hubble, fittingly, was the first observer to use it. Hubble had played a major role in the 200-inch project, having served on the observatory committee responsible for the new telescope.

During the last few years of his life, Hubble suffered from a heart ailment. In spite of an apparent improvement in his condition during his last year, he died of a stroke September 28, 1953, as he was preparing to go to Palomar for four nights of observing.

Hubble's contributions to extragalactic astronomy provided astronomers with the impetus to reach out beyond the confines of our own Galaxy into a universe whose frontiers Hubble pushed beyond the limits of imagination. His discoveries paved the way for modern cosmology and impelled research along many diverse paths. An expanding universe shed new light on Einstein's and others' relativistic speculations about the cosmos, established galaxies as the dynamical units of matter defining large-scale structure, and enabled astronomers to estimate the size and age of the universe.

The fruits of Hubble's research, thirty-six years after his death, have yielded much knowledge about the local universe, but the distant universe remains a world of unfathomed depths. In his book *Realm of the Nebulae*, published in 1936, Hubble wrote that though our knowledge of the universe fades rapidly with increasing distance, the search for knowledge will continue. "Not until the empirical resources are exhausted, need we pass on to the dreamy realms of speculation." That search is Hubble's legacy to modern astronomy. ☐

Brian Jones is a science writer and broadcaster who lives in Bradford, England. His most recent article, "William Herschel: Pioneer of the Stars," appeared in the November 1988 issue.

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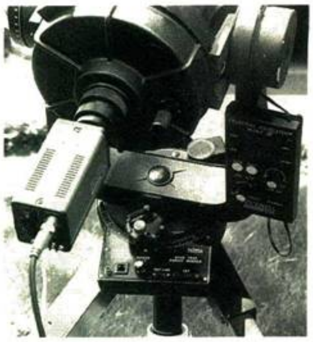

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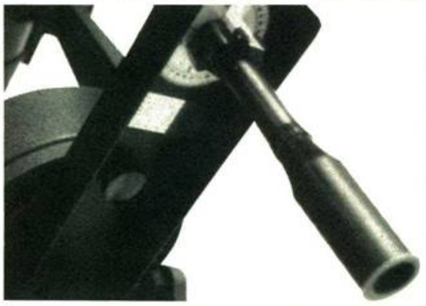

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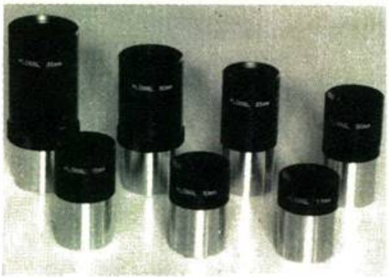

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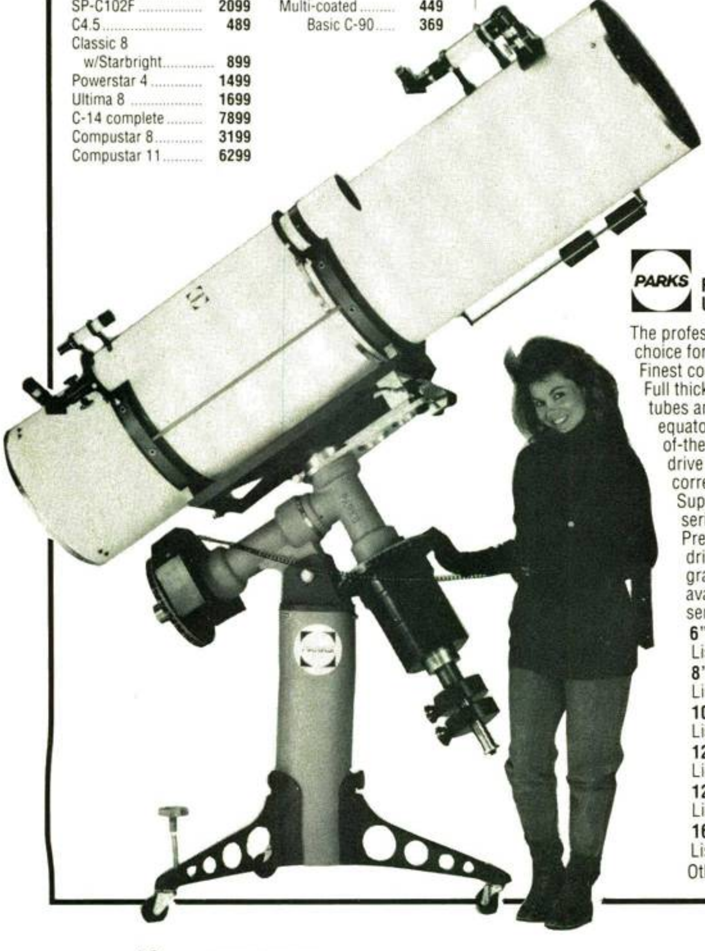

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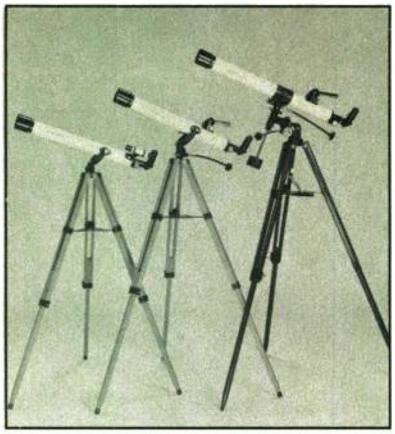

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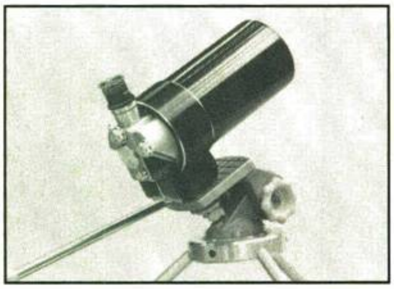

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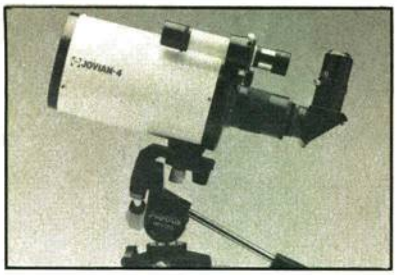

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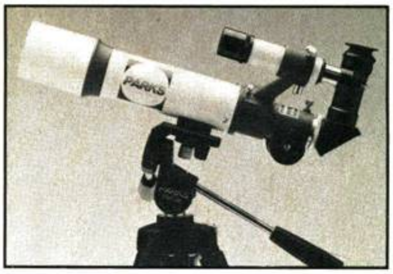

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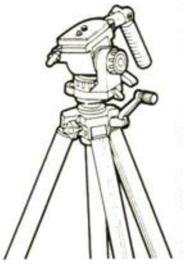

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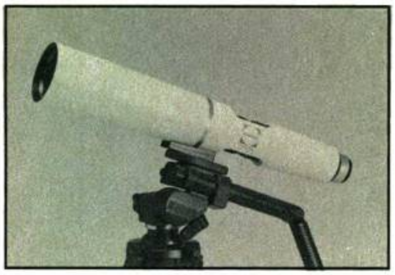

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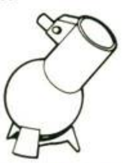

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RESEARCH NEWS

SUPERCOMPUTING THE UNIVERSE

The power of supercomputers enables astronomers to explore the universe that lies beyond the reach of their telescopes.

by Daniel Johnson

In the Heart of the Universe Machine

A major problem in theoretical cosmology is bridging the gap between the Big Bang and the visible universe. For example, how did irregularities such as stars, galaxies, and clusters of galaxies arise from the Big Bang?

Cosmologist Joan Centrella of Drexel University and Adrian Melotte of the University of Kansas used a supercomputer to model ways that "structure" — clumps of particles that later evolved into galaxies and stars — emerged from the Big Bang explosion.

"Graphics often pose problems right from the start," said Centrella. "When you have a multidimensional, highly complex series of calculations, the traditional forms of output — such as printouts of numbers — are virtually useless. You need graphics to debug the code and to analyze and understand the results."

In this example the upper cube maps the density of material in a hypothetical early universe, while the lower cube displays the location of particles.

Astronomy has seen three leaps forward in which a new tool has changed the way we look at the universe. The first tool was the telescope, which opened up the heavens beyond the reach of the naked eye. The second tool was the calculus, which led astronomers to discover the mathematical order underlying the apparent chaos of the universe. The third tool, which has emerged over the last decade or two, is the supercomputer. It has allowed astrophysicists to explore problems that cannot be experimented on directly or are too complicated for a simpler approach.

In 1945 Frank Aydelotte, director of the Institute for Advanced Study in Princeton, pushed his reluctant board of directors into allowing mathematician John von Neumann to build one of the world's first programmable computers. Predicted Aydelotte, "The existence of such a computer would open up to mathematicians, physicists, and other scholars areas of knowledge in the same remarkable way that the 200-inch telescope promises to bring under observation universes that are at the present moment entirely outside the range of any instrument now existing."

Today, astrophysicist Icko Iben, Jr., at the University of Illinois generally agrees. "The analogy is good, provided you don't reserve 'supercomputer' just for the fastest computers available right now. Since the middle 1950s, *every* generation has had its 'supercomputers'."

Supercomputers let astrophysicists pose questions and calculate likely answers, which can then be checked against nature. The faster the computer, the more complicated and realistic are the electronic planets, stars, galaxies, and universes that astronomers can construct.

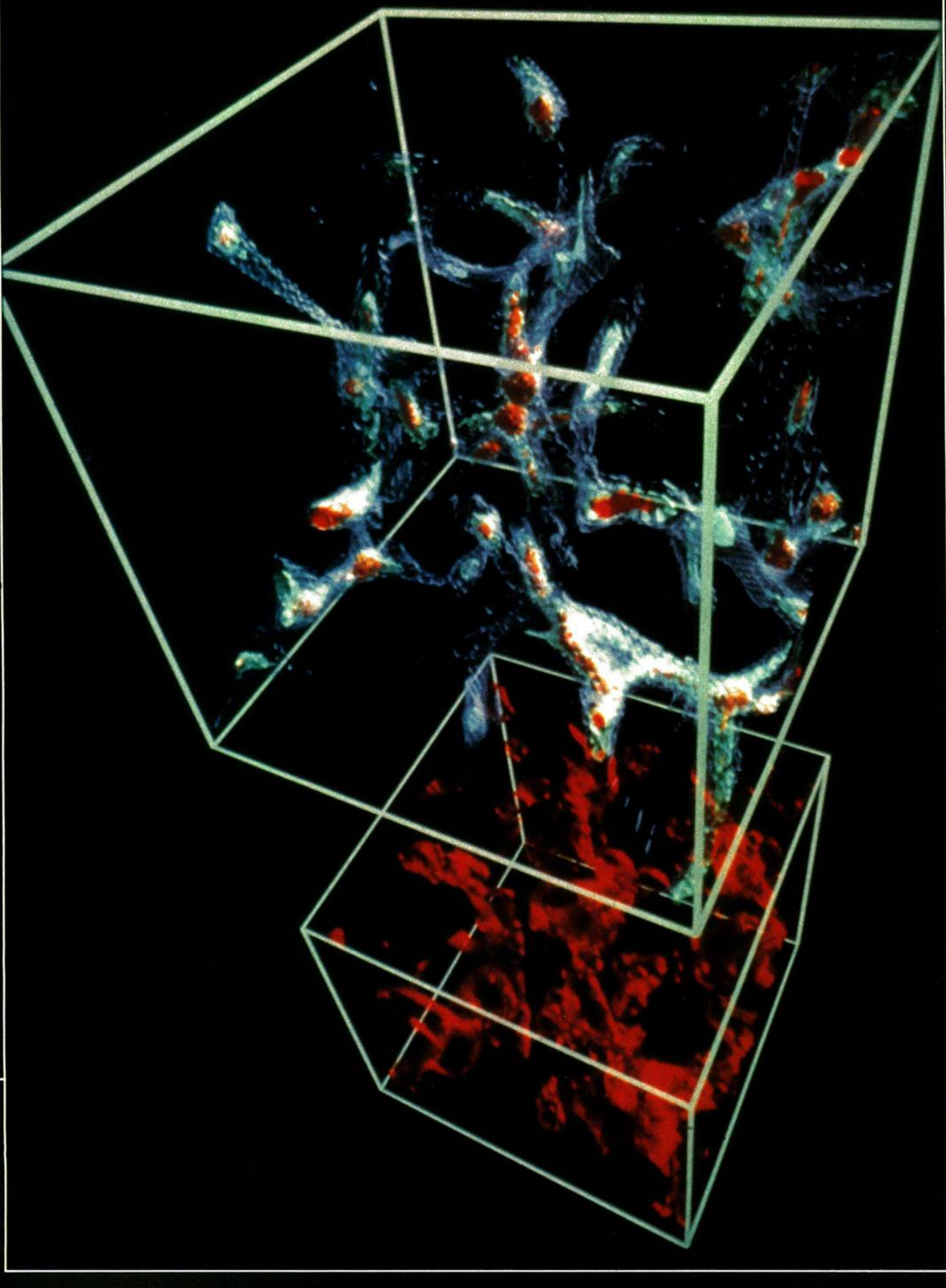
For example, Michael Hjellming of the Dearborn Observatory in Evanston, Illinois, said that supercomputers provide "a great opportunity to study two- and three-dimensional aspects of binary star evolution. The rotation of each star, their revolution about each other, the flow of gas from one to the other, the formation of an accretion disk — all of these have multidimensional aspects that were poorly addressed in the past because we lacked enough computing ability."

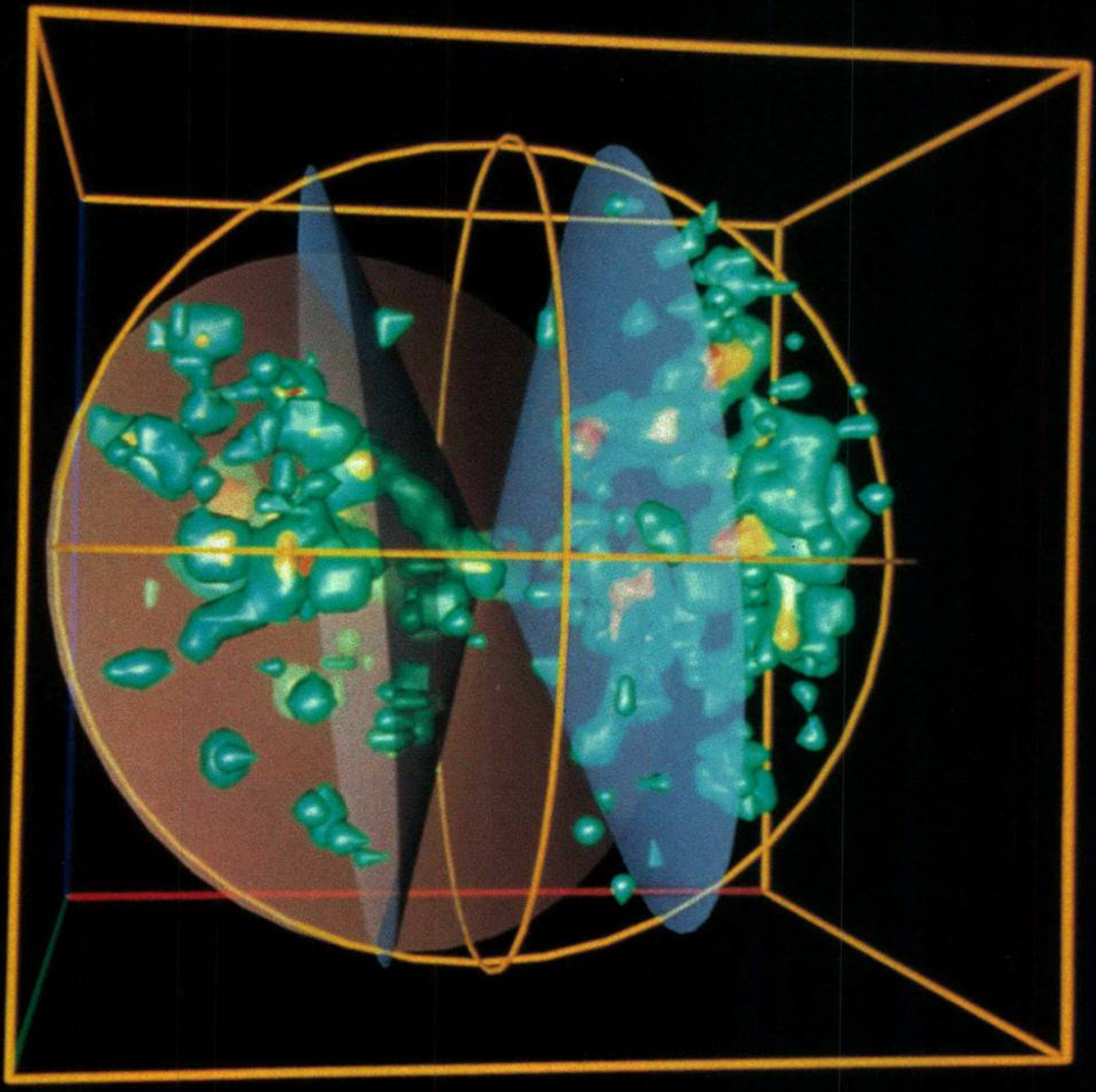
What sets a supercomputer apart from less-super computers? First of all, speed. Just as an Olympic champion is today's fastest runner or highest jumper, a supercomputer is the fastest kind of computer in operation at a given time.

Speed of operation is one factor; a second is parallel processing, an approach to calculating in which parts of the calculations are given to different processors within the machine. The partial results are combined when processing is finished. For example, one supercomputer, The Connection Machine designed by W. Daniel Hillis at MIT's Artificial Intelligence Laboratory, has more than 65,000 processors operating at once. Parallel processing contributes significantly to computer speed. Luckily, said Iben, "Most problems in astrophysics can be separated into component parts for simultaneous solution."

Speed and parallel processing are not enough without powerful algorithms or calculation recipes. One very useful technique is Fourier analysis. Developed in the late eighteenth century by the French mathematician Jean-Baptiste-Joseph Fourier, Fourier analysis asserts that every curve that repeats its shape, no matter what its nature or how long it takes to repeat, can be broken down into a finite number of simple harmonic curves, or sine waves.

Astronomers use Fourier analysis to improve the clarity and detail of images of celestial objects. Supercomputers break the signals from radio





Gauging the Local Supercluster

Even when seen at immensely large distances, galaxies and clusters of galaxies do not "average out" to some uniform distribution but instead fall into groups.

Cosmologist R. Brent Tully of the University of Hawaii created this three-dimensional supercomputer view of the Local Supercluster. The regions of space that contain galaxies are shown in green. (The Milky Way and the Local Group lie at the center; the ring between the two flat cones shows where dust in the Milky Way obscures our view of distant galaxies.)

Probing an X-Ray Binary Pulsar

The star system known variously as Hercules X-1 and HZ Herculis is a busy place: it's an x-ray source, a close binary star, and it contains a pulsar. John Middleditch of Los Alamos National Laboratory combined observations at many wavelengths to compute this model.

Tides from the pulsar, embedded in the accretion disk at right, pull gas from the bloated star HZ Herculis, on the left. Compressed and heated, the gas crashes onto the accretion disk and emits x-rays.

telescopes into sine-wave components with Fourier transforms; the components are then adjusted to enhance certain features and remove others — much as noise can be removed from the Fourier transforms of recorded music. The transformed data are then converted back into an image.

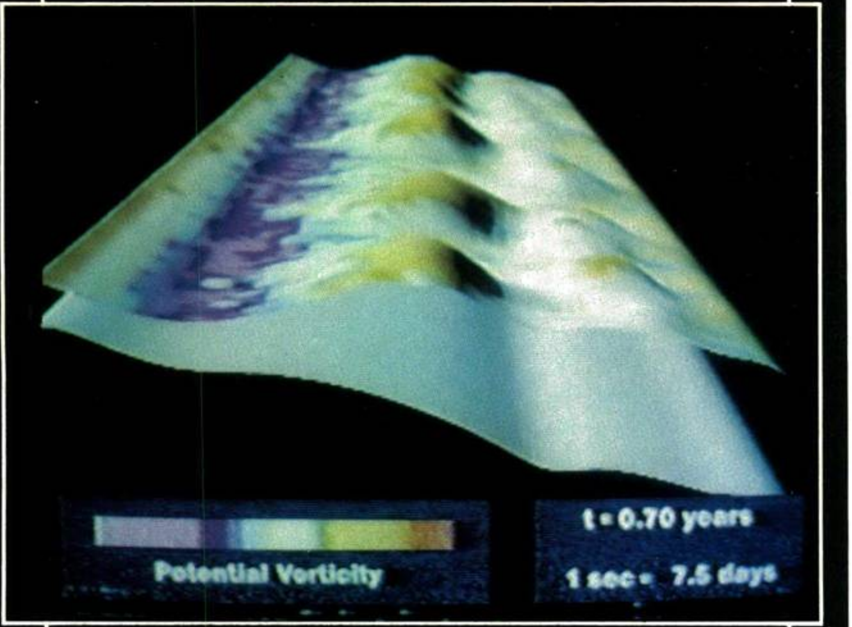
Speed, processing, and sophisticated algorithms provide payoffs for astrophysicists who want to understand what goes on inside a star. Icko Iben, Jr., studies intermediate-mass stars both in isolation and in close binary systems. He says that in many problems "the equations are embarrassingly simple. The complexity arises from the fact that each system contains many parts coupled to one another, so many arithmetical operations are needed."

Iben's model star has 500 concentric shells. He specifies how pressure, temperature, and density vary at each shell's boundary. Then, to locate each shell and determine the gravitational force on it, he tabulates the distance from the center of the model to each shell boundary and the mass of all the shells between the center and the shell. Finally, his model tracks the energy flowing across each shell boundary. In all, the computer juggles 16 variables at each of the 500 shell boundaries.

"It would take a single person about 3,000 years to model an evolving star by hand," said Iben. "After paring down to essentials and using every computational trick known, a clever person might obtain roughly the same results after a lifetime of effort. The problem is during that lifetime most of the equations would have become hopelessly out of date."

Iben noted that this model is the *simple* one — it follows a star's evolution through only the hydrogen and helium burning stages. Several hundred more variables are needed to describe more advanced stages of stellar evolution. By the time his model was complete, the computer was keeping track of about 25,000 variables and performing about 10 million operations. "With a standard computer back around 1970, this would take about eight hours of computing time," Iben concluded. Today, running this stellar model using a more complicated approach and still more variables takes a fraction of an hour on a Cray supercomputer.

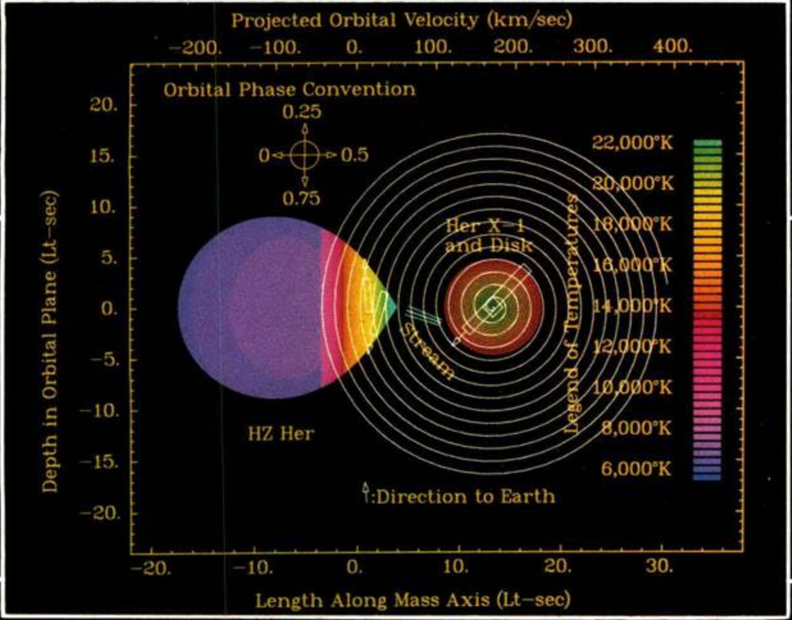
Gene Milone and his colleagues at the University of Calgary use a Cyber 205 supercomputer to study the light curves of eclipsing binary systems. Their work is a good example of how faster computers with improved models have extended astronomy into

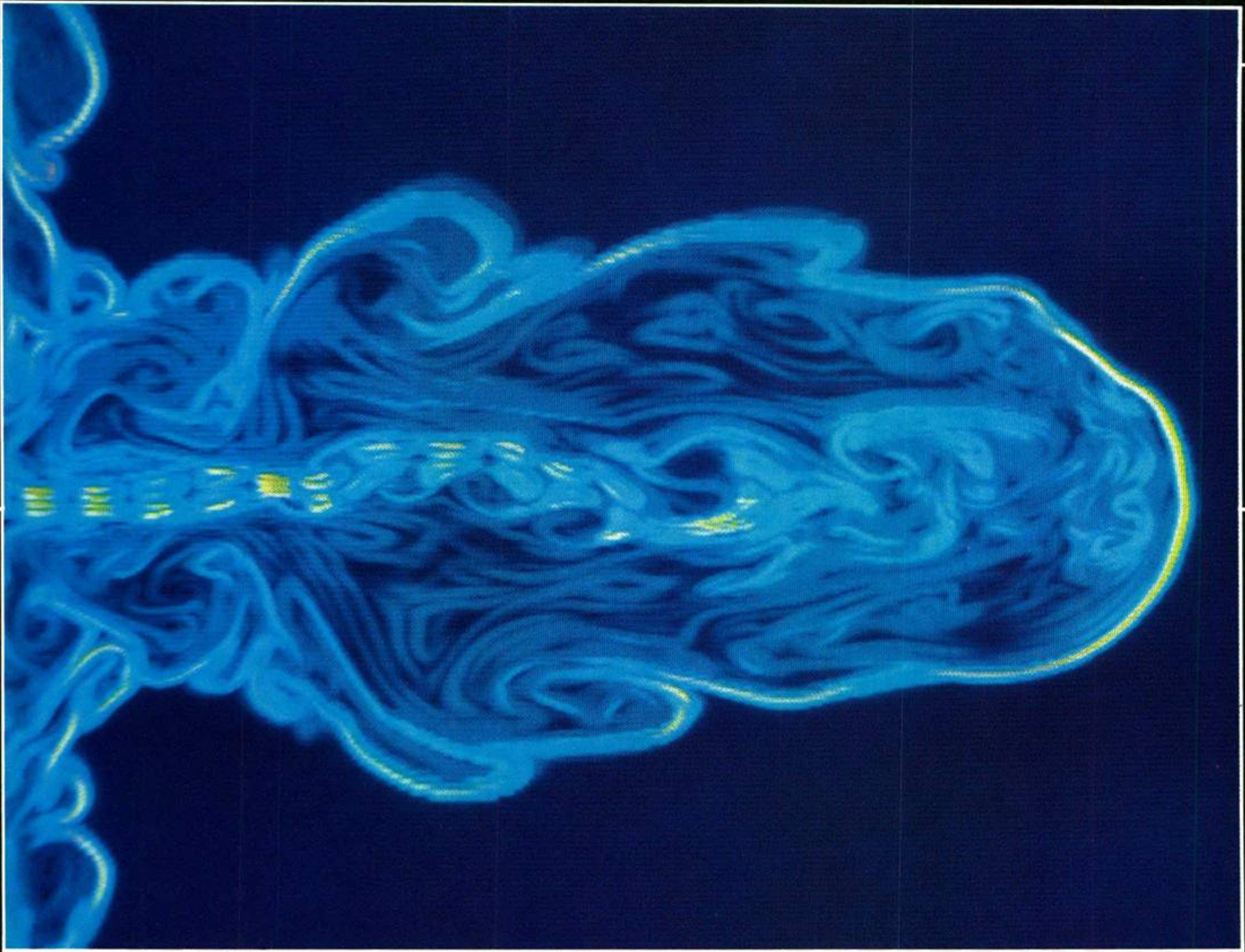


Modeling Jupiter's Great Red Spot

The Jupiter that emerged from the *Voyager* encounters was vastly more complex than anyone ever dreamed, and understanding how Jupiter "works" is difficult. Planetary scientists Timothy Dowling of Cornell University and Andrew Ingersoll of the California Institute of Technology are investigating one aspect of this task: explaining the origin of the Great Red Spot. They created a model Jovian atmosphere in a supercomputer, put in the wind velocities measured by *Voyager*, and set the model running.

They found that, over time scales measured in Earth weeks, rising currents of material formed "mountains" that are spun like roller bearings by the eastward and westward flow of the adjacent belts and zones. These great upwellings arose spontaneously from the atmosphere's turbulence and frequently merged to form large and lasting vortices like the Great Red Spot.

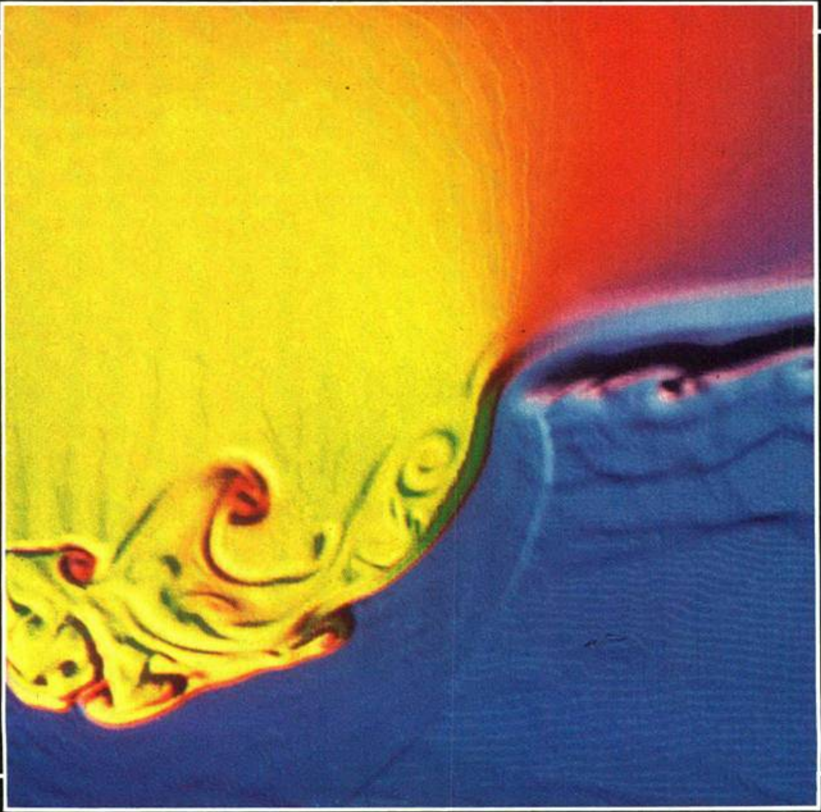




The Plasma Clouds of Venus

When planetary scientists Robert Wolff of the Jet Propulsion Laboratory and Michael Norman of the University of Illinois wanted to investigate the interaction of the solar wind and Venus, they first created a two-dimensional model of the planet's outer atmosphere in a supercomputer. They then introduced changes in the model, reran the computer model, and saw how the outcome was altered. The results are then compared to spacecraft observations and — hopefully — new insights emerge.

In this view, the hot solar wind is flowing from the left. By tracking how the turbulent eddies grow and die, Wolff and Norman can study the formation and evolution of plasma clouds at the Venusian ionopause.

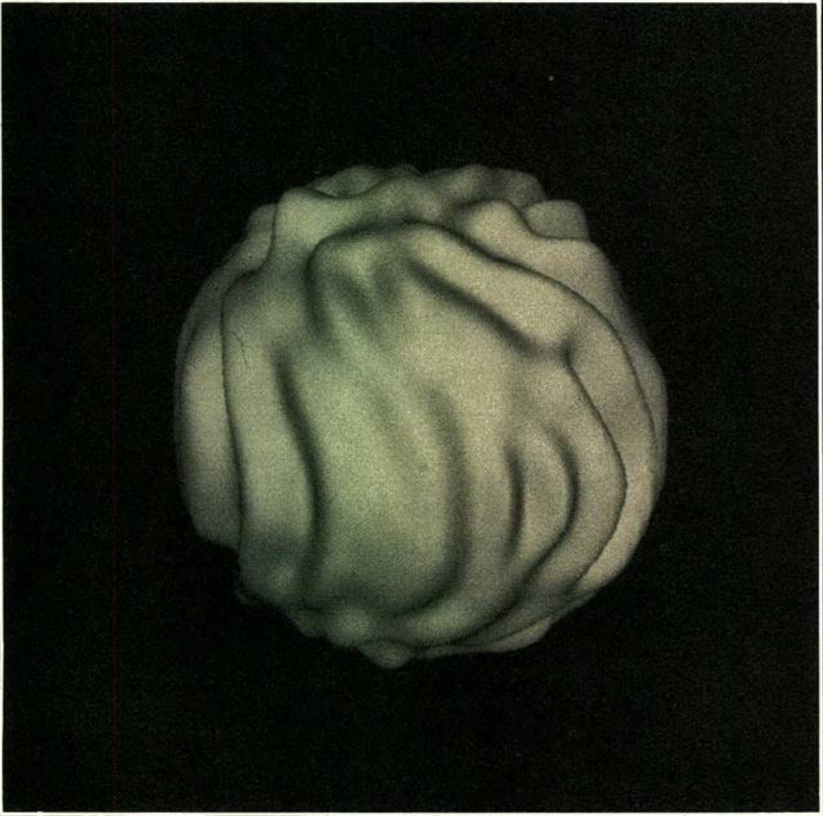


Jets into the Void

Space is never as empty as it looks, and even the vast, seemingly empty gulfs between the galaxies contain material. Astrophysicists Philip Hardee of the University of Alabama and Michael Norman of the University of Illinois are studying what happens when a jet of material (from an active galaxy, for instance) tears into this intergalactic medium at supersonic speeds.

In this supercomputer simulation Hardee and Norman assume that the jet carries a magnetic field that partially controls the way the jet breaks up into turbulent eddies. The flow and stream lines in the picture trace the knotty twists in the magnetic fields.

Countless simulations like this result in a better understanding of the structure of the vast clouds of gas that radio telescopes have observed jetting from the nuclei of certain explosively active galaxies and provide a clearer picture of the environment surrounding the galaxies.



A Look inside the Sun

Theoretical astrophysicist Gary Glatzmaier of the Los Alamos National Laboratory used a supercomputer to examine the physical properties and the roiling behavior of matter inside the Sun. His solar model uses more than half a million grid points and follows what happens through more than 30,000 discrete time steps.

This computer simulation of the Sun shows the up-and-down flows of material at a depth halfway to its center. Regions of rising gas show as ridges, while valleys show the sinking currents. (Both ridges and valleys are skewed because the Sun rotates.) Analysis of the computer model's results show that the equatorial region should be sped up relative to the higher latitudes, which matches what solar astronomers have long observed.

otherwise closed areas. "Binary stars are the only direct source of our knowledge of the masses of stars," said Milone. "Our goal is to determine both the physical properties and evolutionary states of such systems."

The earliest techniques for modeling light curves originated with Henry Norris Russell at Princeton in 1910. He assumed that stars were uniform spherical bodies. In cases involving tidal distortion (true in all close binaries), a process of "rectification" had to be carried out. This process, in principle at least, freed the light curves of the effects of distortion and the mutual reflection of each star's light. This technique was more fully developed by John Merrill, currently at the University of Florida.

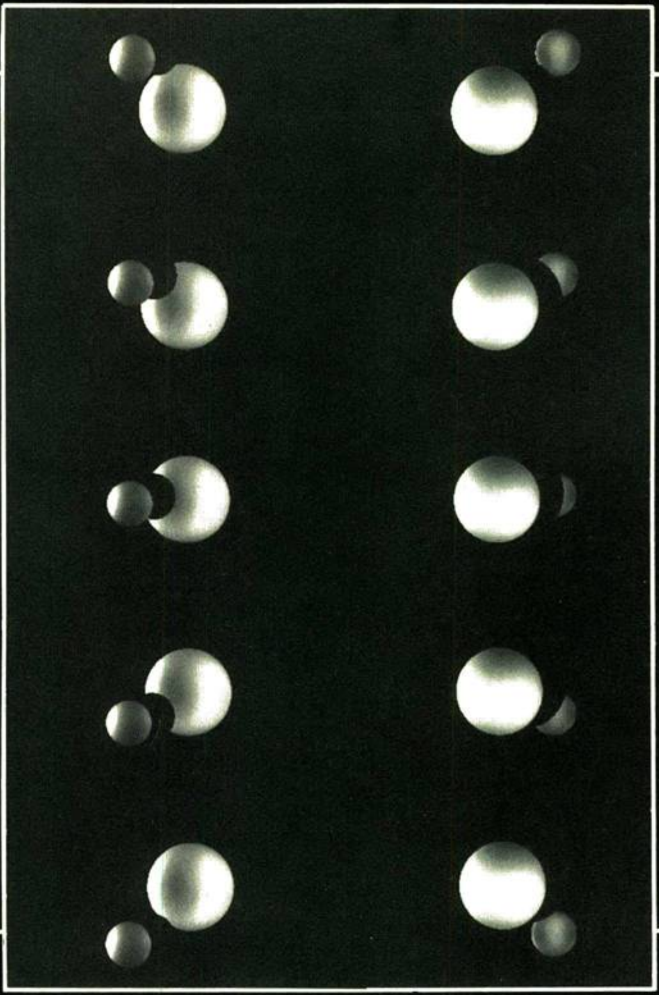
However, the Russell-Merrill technique turns out to be deficient in cases where binary stars are so close that they touch, because the technique makes several inflexible assumptions about the shapes of stars. Milone and his colleagues therefore began to use what he calls "the world's most powerful synthetic light-curve program."

Once Milone calculates a valid, but approximate, set of data for a system, he changes certain values slightly — the mass ratio, for instance — and computes a new synthetic light curve. He compares this to the real light curve. This iteration process is repeated until the adjustments fall below the accepted error ranges. Milone said, "We have succeeded not only in modeling the basic light and velocity variation in contact binaries, but in accounting for perturbations as well. This is a major new step."

Supernova research also relies on supercomputers. Supernovae are classified into Types I and II, although it is becoming clear that there are theoretical overlaps and some examples do not fit neatly into either classification.

Craig Wheeler and Robert Harkness of the University of Texas used a Cray supercomputer to model supernova explosions in an attempt to understand why some supernovae are not clearly either Type I or II. The computer model was based on work by David Branch of the University of Oklahoma.

"We model the expanding supernova atmosphere as a set of concentric shells, each with a specific composition, density, temperature, and velocity," Wheeler said. They then compute the flow of radiation through the shells, calculating how light is generated, scattered, or absorbed by the atoms and ions that the light encounters on its way out of the exploding star. "The result of the



Mapping the Face of Pluto

Since March 1985, Pluto's moon Charon has been passing alternately in front of and behind Pluto in a series of mutual eclipses and occultations that will continue until October 1990. Although the two objects merge into a starlike point in a telescope, the mutual events produce small changes in brightness that are easy for instruments to detect.

Astronomers Keith Horne and Marc Buie of the Space Telescope Science Institute and David Tholen of the University of Hawaii took the brightness changes and put this problem to a supercomputer: Given a knowledge of Pluto and Charon's relative positions, how big is each object and what markings on their surfaces would most likely explain the observed variations in brightness?

The simulation at left depicts the transit of Charon on February 6, 1989, and its occultation by Pluto three days later. (The sequence begins at upper left, goes down the left column, and then up the right column.) Computer analysis has shown that Charon is about half Pluto's size and that Pluto has a dark equatorial band.

computation is a predicted spectrum of light from the explosion that we can compare to the real thing."

Wheeler and Harkness' conclusion, unreachable without a supercomputer, is that the physics of supernovae don't fit comfortably into any neat, established types. "As our understanding of supernova explosions evolves, the existing classification scheme will inevitably become less important."

Just as we realize the immense impact that supercomputers of the 1980s have on astronomical research, we discover that super-supercomputers apparently lie just ahead. The road to them, however, isn't an open highway. Circuit technology is posing major constraints on computer speed. As circuits get smaller and faster, the switches that lie at the heart of the circuits begin to be affected by the operation of other switches nearby and may not operate reliably. Another problem is heat removal — keeping tightly crowded circuits cool enough to function properly.

But, said Robert Bate, a physicist with Texas Instruments, "the very phenomena that impose size limits on ordinary circuits could be exploited in a new generation of vastly more efficient devices. These devices work on quantum-mechanical effects that carry semiconductor technology into a realm of physics where particles behave like waves and pass through formerly impenetrable barriers. With quantum semiconductor devices such as the Josephson junction, I believe it's possible to put the circuitry of a supercomputer on a single chip."

Other problems center on software, or "code" as it is called: creating it, maintaining it, and adapting it to new uses. Ron Mayle of the Lawrence Livermore National Laboratory said, "Future machines will allow more improvement of the numerical models. However, to make progress we will need larger group efforts with more people working solely on the computer code." Big defense laboratories often have dozens of people working on the computer code alone. "The old one- or two-person effort won't be enough. The code will become larger than what just a couple of people can be familiar with," said Mayle.

The increasing complexity of computer software may not be a serious problem after all, according to computer scientist David Kuck of the University of Illinois. "What's going to happen in the next decade is that we're going to figure out how to make parallelism work," said Kuck. Nonetheless, astronomy in the next century will become more of a team effort, with individuals committing themselves to research projects earlier and staying with them for years, if not their whole career.

"Ah, but a man's reach should exceed his grasp, or what's a Heaven for?" wrote the poet Robert Browning. The telescope, the calculus, and the supercomputer have each tangibly and immeasurably increased the astronomer's reach, and a new universe has fallen into our grasp. What will the future bring? If the past is any guide, we can expect whatever new tool we invent to unlock an even more wonderful universe than we have at present. ☐

Daniel Johnson is an amateur astronomer and computer consultant who lives in Calgary, Alberta.

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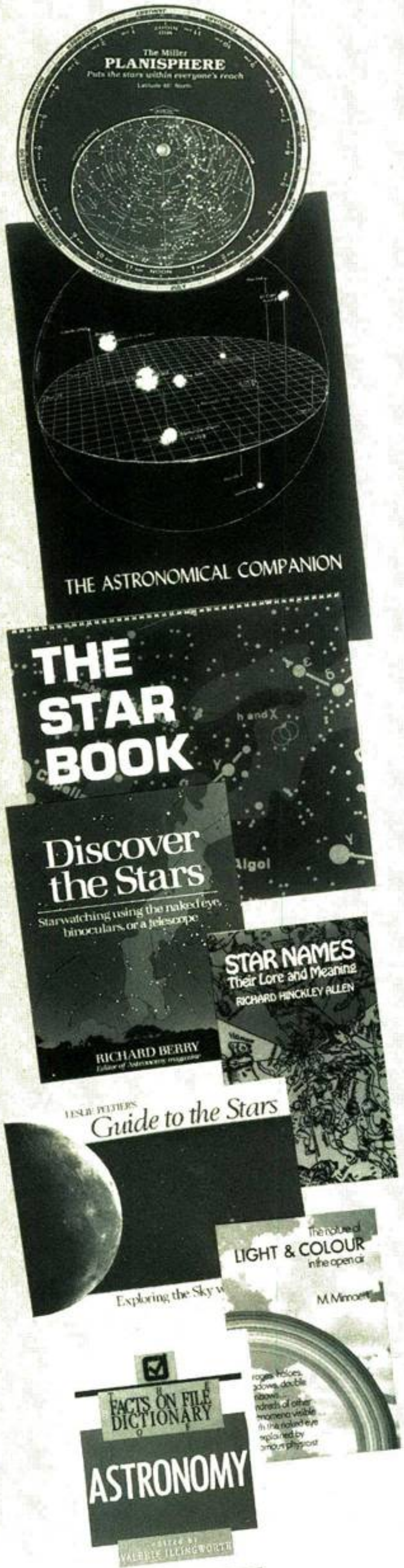
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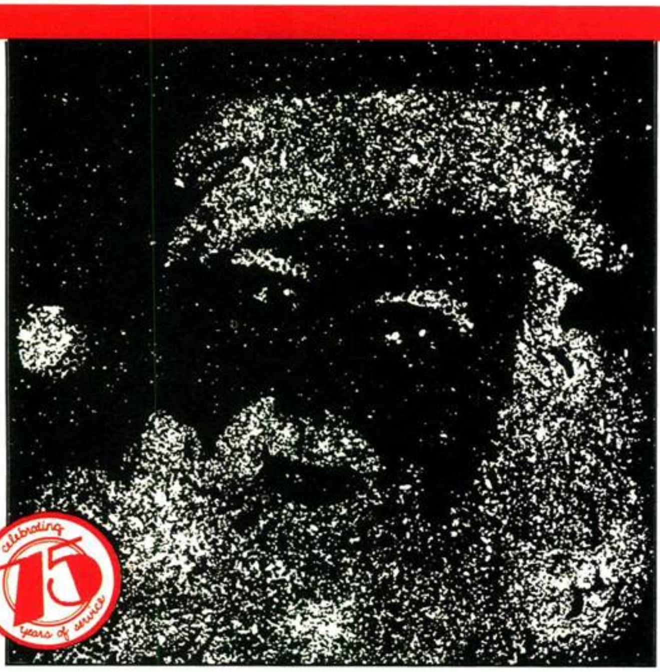

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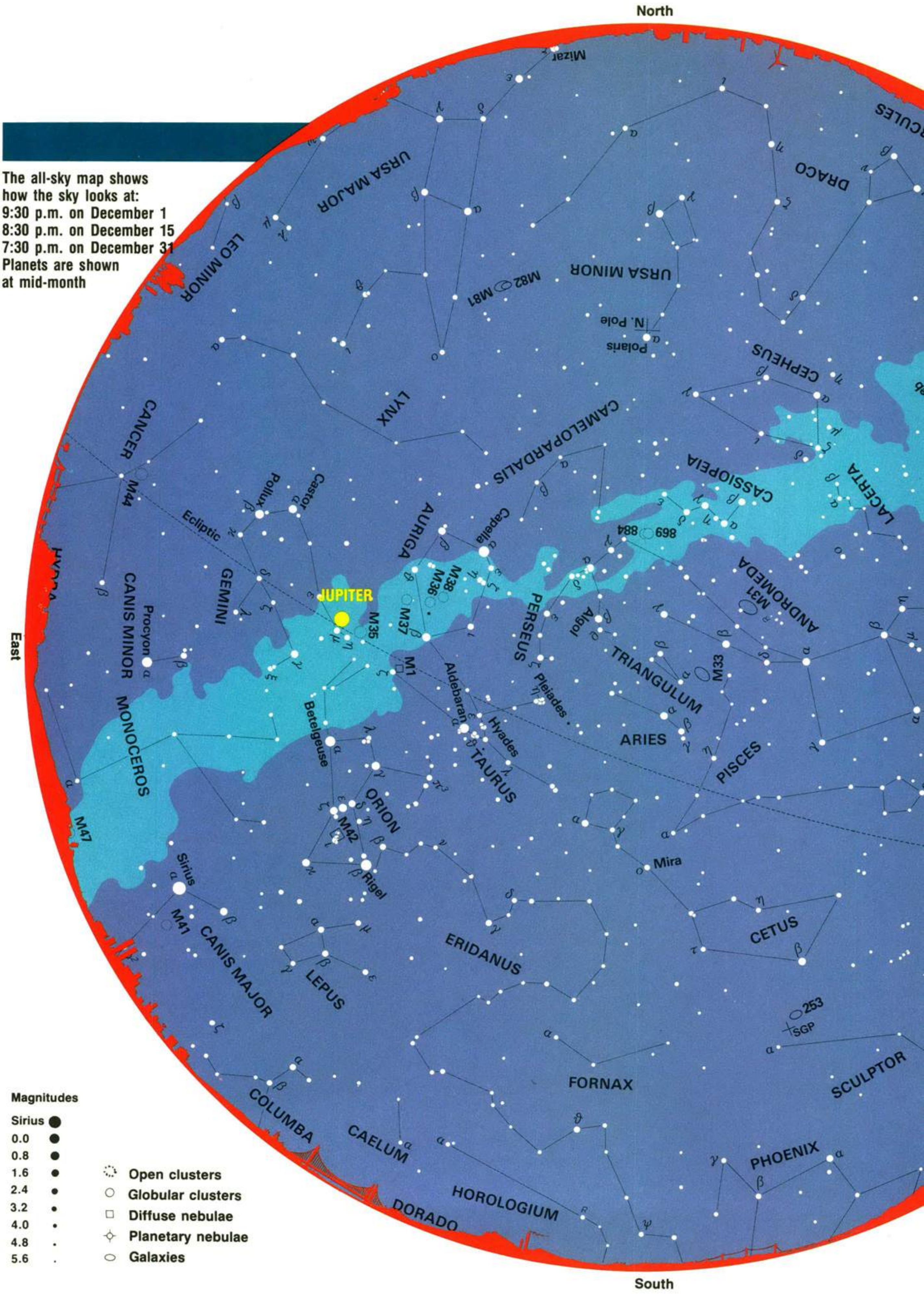
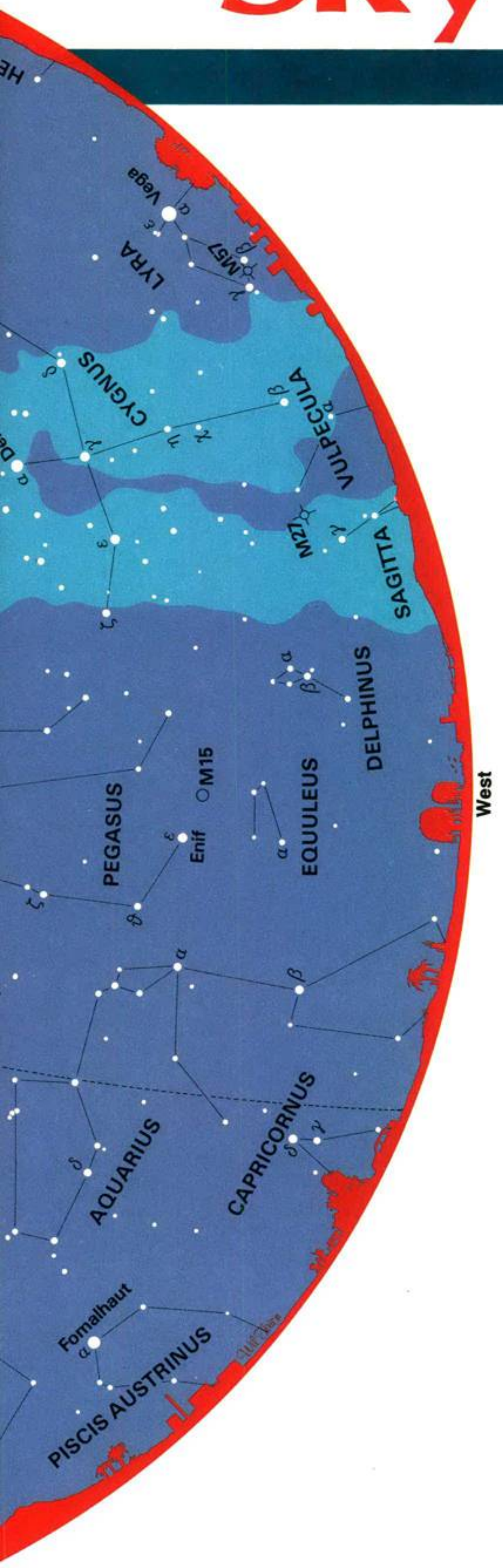
The all-sky map shows how the sky looks at:
9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31
Planets are shown at mid-month


North
East
South
URSA MAJOR
Mizar
LEO MINOR
DRACO
URSA MINOR
M82
M81
N. Pole
Polaris
CEPHEUS
LYNX
CAMELOPARDALIS
CASSIOPEIA
LACERTA
CANCER
M44
Pollux
Castor
Ecliptic
AURIGA
Capella
869
884
ANDROMEDA
M31
GEMINI
CANIS MINOR
Procyon
JUPITER
M35
M37
M36
M38
PERSEUS
Algol
TRIANGULUM
M33
M1
Aldebaran
Pleiades
Hyades
TAURUS
ARIES
PISCES
Betelgeuse
MONOCEROS
ORION
M42
Rigel
M47
Sirius
M41
CANIS MAJOR
LEPUS
ERIDANUS
Mira
CETUS
253
SGP
FORNAX
SCULPTOR
COLUMBA
CAELUM
HOROLOGIUM
DORADO
PHOENIX
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

DECEMBER 1989



JUPITER AT ITS BEST

It's hard to miss Jupiter this month. The giant planet is visible from dusk to dawn and shines at magnitude −2.7, its brightest for the year. Telescopic observers can watch for further changes in Jupiter's faint South Equatorial Belt.

VENUS BRILLIANT IN EARLY EVENING

Venus offers something for all stargazers in December. For naked-eye observers the planet is blazingly bright, at magnitude −4.7, in the southwest after sunset. For telescopic observers Venus grows 60 percent in apparent diameter, while its illuminated crescent shrinks by 70 percent.

BRIGHT COMET IN NOVEMBER

The newly discovered Comet Okazaki-Levy-Rudenko should be bright enough to see with the naked eye during November and may sport a long tail. Look for the comet low in the east to southeast before dawn.

Dates and Times

1 The Moon passes 3° south of Saturn, 2 a.m. EST

2 The Moon passes 0.8° north of Venus, 3 a.m. EST

5 First Quarter Moon is at 8:26 p.m. EST

6 Nausikaa is at opposition

10 Mercury passes 2° south of Uranus, 8 a.m. EST
The Moon is at perigee (224,507 miles from Earth), 5:36 p.m. EST

12 Full Moon is at 11:30 a.m. EST

13 The Moon passes 3° north of Jupiter, 3 p.m. EST
Geminid meteor shower peaks

14 Venus is at greatest brilliancy (−4.7 magnitude)
Mercury passes 3° south of Neptune, 11 p.m. EST

16 Mercury passes 2° south of Saturn, 5 p.m. EST

19 Last Quarter Moon is at 6:54 p.m. EST

20 Ceres is at opposition

21 Winter solstice is at 4:22 p.m. EST

22 Ursid meteor shower peaks
The Moon is at apogee (251,792 miles from Earth), 2:29 p.m. EST

23 Mercury is at greatest eastern elongation (20°)

27 Uranus is in conjunction with the Sun
Jupiter is at opposition
New Moon is at 10:20 p.m. EST

30 The Moon passes 2° south of Venus, 5 a.m. EST
Mars passes 5° north of Antares, 6 p.m. EST

Eye on the Sky by Deborah Byrd

VENUS AT ITS BRIGHTEST

Although it is always the brightest planet, Venus is even more brilliant than usual this month. On December 14 the planet shines at a magnitude of −4.7 — its brightest magnitude this year — and it is no fainter than magnitude −4.6 throughout December. Look for Venus low in the southwestern sky during and just after twilight.

Make a special effort to look for Venus on December 1, when it lies very close to the slender crescent Moon. (Viewers in eastern Asia and Japan can see the Moon pass directly in front of Venus.) In the Western Hemisphere observers along the Pacific Coast have the best view of the conjunction as Venus lies about 3° from the Moon. However, observers on the East Coast can still see the objects close to each other.

Venus' greatest brilliancy occurs when Venus and Earth are near each other in their orbits. In mid-December Venus lies about 37 million miles away, its nearest since it emerged from the Sun's glare last May. Because it is closer, it appears larger in our sky and reflects more sunlight in our direction, making it appear brighter.

Venus gets even closer to Earth in January, when it passes nearly between us and the Sun. Why isn't Venus brightest then? The answer is hidden to the naked eye but quite obvious through a small telescope — Venus' disk is only narrowly illuminated from our perspective. Although one half of the planet is always lit by the Sun, most of that lit half is now facing away from us. Greatest brilliancy occurs when Venus is near enough to present a large disk, but not so close that its phase is too narrow a crescent.

If you own binoculars, this is a good month to try to see the crescent shape of Venus. Observe Venus shortly after sunset, when there is less contrast between Venus and the background sky, and near the end of the month, when Venus is larger and less fully illuminated. If you hold the binoculars steady (try sitting on the ground with your elbows braced against your bent knees) you should see that Venus appears less than round.

When at greatest brilliancy, Venus shines with a peculiar, unearthly light. At such times the planet is often reported as a UFO. What's more, we're not the first generation to become jittery at the sight of this brilliant planet. In *Watchers of the Skies*, Willie Ley tells of a French harbor commandant who ordered a gunboat out to sea to shoot Venus down in 1835. Apparently, he mistook the planet for an enemy balloon.

BRILLIANT JUPITER is at its best during December and reaches opposition on the 27th. Jim Baumgardt photographed the planet near opposition last year as it rose over Mount Shasta.

JUPITER REACHES OPPOSITION

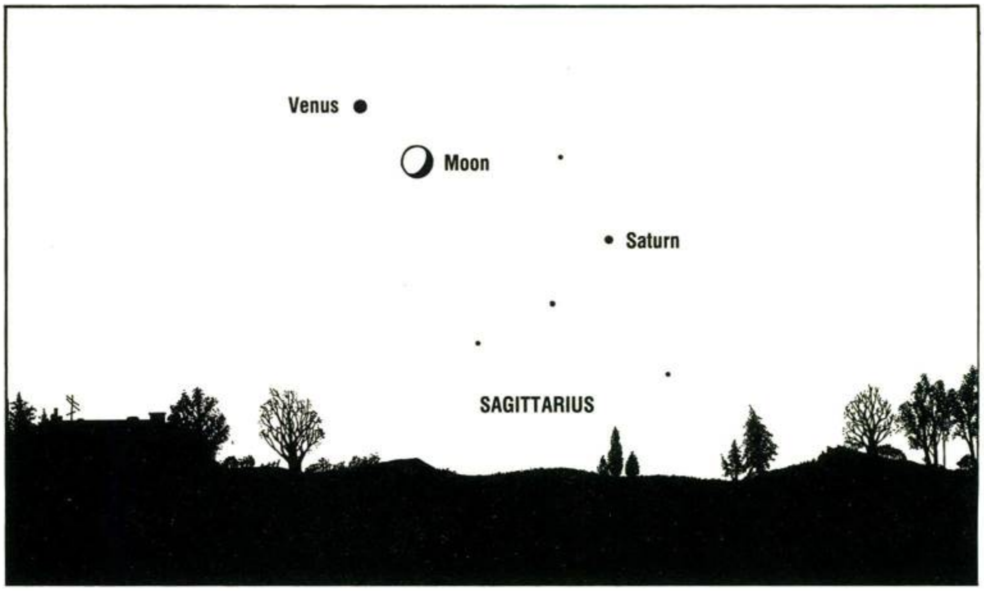
While Venus is shining brightly in the southwest, the second brightest planet comes into view in the east-northeast. Jupiter rises at the end of twilight in early December and comes up progressively earlier as the month continues. On December 27 when Jupiter reaches opposition, it rises at sunset, is high overhead at midnight, and sets in the west at dawn.

At opposition Jupiter lies directly opposite the Sun from Earth. The giant planet is then nearest Earth, just under 400 million miles away. Because Jupiter is always nearly fully lit as seen from Earth, the planet reaches peak brightness, magnitude −2.7, at opposition.

Jupiter spends all of December in Gemini. It is now in an excellent place to be observed with binoculars or a small telescope, riding high on the ecliptic as viewed from the Northern Hemisphere. With steadily held binoculars you can often see one or two of the planet's four largest moons, the famous Galilean satellites, when they are far from the overwhelming brightness of Jupiter itself.

A MOST SOUTHERLY SUN

The Sun is at its farthest point south on the celestial sphere at 4:22 p.m. EST on December 21. This solstice marks the beginning of winter for the Northern Hemisphere and summer for the Southern Hemisphere. For those of us in the Northern Hemisphere, the solstice is the shortest day of the year. However, the earliest sunset occurs about two weeks before the solstice and the latest sunrise about two weeks after.



THE MOON JOINS VENUS in the evening sky on December 1. Look for the two objects low in the southwest during the gathering twilight.

DECEMBER'S TWO METEOR SHOWERS

The Geminid meteor shower is normally one of the year's best, but this year's shower peaks just a day after Full Moon, which drowns out all but the brightest Geminids. Therefore, the best meteor shower of the month is the Ursids, which peak on the morning of December 22. This shower generally produces ten to fifteen meteors per hour, though the rate at some locations was as high as one hundred per hour in 1986. A waning crescent Moon rises at about 2 a.m. and thereafter interferes slightly with the shower. But if the holiday season has you longing for a quiet time under the stars, the Ursids provide a good opportunity.

DECEMBER'S PLANETS

Saturn is very low in the southwest after sunset early in the month, where it shines at a not very bright magnitude of 0.5. By the latter part of December, the planet, along with its host constellation Sagittarius, disappears into the Sun's glare.

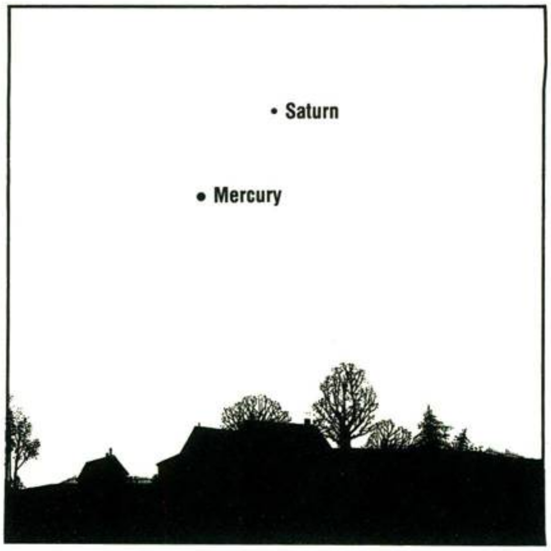
Venus shines with an eye-catching brilliance from the southwestern sky each evening. In addition to the close conjunction with the crescent Moon on the 1st and greatest brilliancy on the 14th, Venus is also high in the evening sky during December. During the first half of the month, Venus sets three hours after the Sun and more than an hour after the end of twilight. By the end of December, Venus has started plunging toward the horizon and sets about two hours after the Sun. Venus will disappear from view in the middle of January and then reappear low in the east before sunrise in late January.

The evening sky also plays host to Mercury this month, but the innermost planet is much more difficult to see than Venus. Mercury reaches greatest elongation — its greatest apparent distance from the Sun — on December 22/23, when it lies 20° east of the Sun. Although 20° is not a large separation, this is a reasonably favorable apparition for Mercury because the ecliptic makes a fairly steep angle with respect to the western horizon on December evenings.

The best time to search for the elusive planet is on December 16, when −0.6-magnitude Mercury lies just 2° south of 0.5-magnitude Saturn. Mercury climbs a bit higher in the sky over the next week to ten days and should be fairly easy to spot.

After Venus sets in the early evening, Jupiter dominates the sky for the rest of the night. The giant planet reaches opposition on December

SATURN AND MERCURY pass within 2° of each other on the evening of December 16. The two planets appear very low in the southwest about thirty minutes after sunset.



27, when it shines brilliantly at magnitude −2.7. Jupiter lies in the constellation Gemini, a region littered with bright stars, but the planet outshines them all.

Mars is the only planet you have to get up before dawn to see. The Red Planet shines low in the southeast at magnitude 1.6 and would be rather inconspicuous if it were not moving through a region of the sky populated by some noticeable stars.

Mars begins December in the constellation Libra but moves into Scorpius after mid-month. There it sweeps past "the crown of the scorpion," which consists of three stars in a little arc. It then sweeps 5° north of the brightest star in Scorpius, orange-red Antares, on December 30. The name Antares means "rival of Mars," a name derived from the star's brilliance and Mars-like hue. When Mars passes its rival in late December, Antares is the brighter of the two at magnitude 1.0.

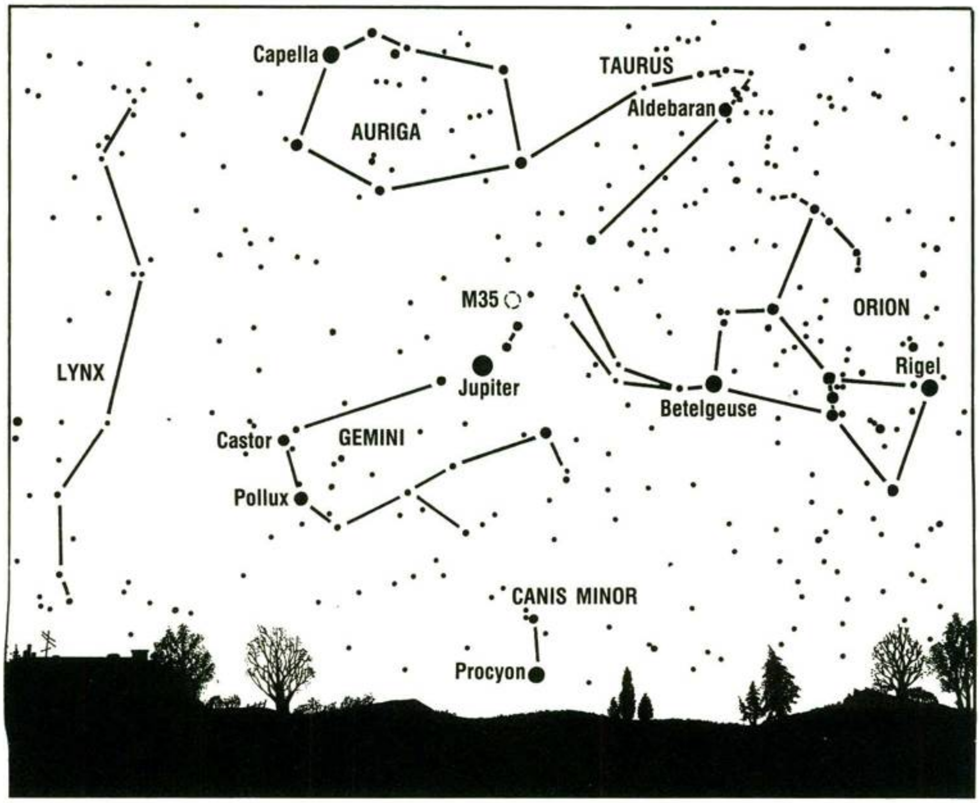
DECEMBER'S STARRY SKY

The giant planet Jupiter is easy to spot as the brilliant object in the east each evening and in the west each morning. The planet is located in the constellation Gemini the Twins; Gemini's two brightest stars are Castor and Pollux.

Castor and Pollux are conspicuous because they are both among the twenty-five brightest stars in the sky and lie just 4.5° apart. They are so tied to the idea of "twins" that you might expect them to look alike, but they do not. At magnitude 1.6, Castor is noticeably fainter than Pollux, which shines at magnitude 1.1. Also, Castor shines bright white, while Pollux is distinctly golden in color.

Although Castor is fainter than Pollux, it is designated the Alpha star of Gemini. That title was usually given to the brightest star in a constellation, which raises the interesting possibility that Castor may have been brighter hundreds of years ago than it is now. Castor is also the more interesting star. It appears as two stars through a 4-inch telescope at high power, and a third component lies nearby. Each of these stars also consists of two stars — unfortunately not visible in a small telescope — which makes Castor a system of six stars in all.

GEMINI IS PROMINENT in the east on December evenings. Use Jupiter as a guide to find the constellation and its two brightest stars, Castor and Pollux.



Befitting the presence of Jupiter in their vicinity this year, Castor and Pollux are related to Jupiter in mythology. The Greeks called the stars the "sons of god," because according to some myths they are the mythological offspring of the king of the gods, Zeus (who was Jupiter in Roman mythology). Their mother was Leda, wife of King Tyndareus, whom Zeus had ravished while in the form of a swan. Castor and Pollux supposedly sprang from swan eggs, each in the company of a sister — Clytemnestra and Helen. Castor and Clytemnestra, however, were mortals because they shared a half-mortal parentage, while Pollux and Helen were immortal.

The two brothers looked identical and were inseparable. When his brother was slain in battle, Pollux refused to live without him. This display of brotherly love was rewarded when both twins were placed together in the sky.

Through the Eyepiece by Rick Shaffer

FOCUS ON JUPITER'S ATMOSPHERE

The dramatic fading of Jupiter's South Equatorial Belt mentioned in last month's column has left the giant planet with only one prominent equatorial belt. As of early September, the South Equatorial Belt remained very faint and showed no signs of returning.

The South Equatorial Belt is almost certain to return to prominence. The only questions are when and how rapidly it will intensify. Jose Olivarez, Jupiter recorder for the Association of Lunar and Planetary Observers, sees a strong resemblance between Jupiter's present appearance and the planet's appearance in both 1928 and 1958, when the South Equatorial Belt was similarly faint. In both years the South Equatorial Belt intensified rapidly, even explosively, and Olivarez expects a similar violent revival for the South Equatorial Belt this time. No one knows for sure when this will happen, however. Estimates range from sometime within the next couple of months to a year or more from now.

Because there is so much uncertainty as to what Jupiter's atmosphere will do next, it's a good idea to observe the planet frequently. Fortunately, this is the perfect month to do so: Jupiter reaches opposition on December 27 and is visible all night long.

Even better, this is a particularly favorable opposition for Northern Hemisphere observers. Because Jupiter is at opposition (opposite the Sun) only six days after the winter solstice, when the Sun is at its farthest point south in our sky, Jupiter is very near its farthest point north. For observers in the Northern Hemisphere, this means Jupiter passes nearly overhead. At a latitude of 40° north, Jupiter lies just 17° from the zenith at local midnight.

Jupiter's close zenith passage offers two advantages to observers. First, if you observe around local midnight, when Jupiter is highest in the sky, the planet is well above much of the turbulence that causes poor seeing. By midnight the sources of turbulence also have had time to radiate much of the heat they stored during the short winter day.

In selecting an observing site, then, keep in mind that the light from Jupiter is traveling mainly through the atmosphere right above your head. You should still avoid large buildings, parking lots, and other obvious sources of heat, but if these are a fair distance away they won't affect seeing as much as they usually do. Concentrate instead on choosing an observing site with no heat sources in the immediate vicinity.

The second advantage to Jupiter's close zenith passage is that the planet remains high in the sky for a long time. Jupiter rises at sunset and sets at sunrise during this opposition. Thus, for those of us at mid-northern latitudes, Jupiter is above the horizon for over fourteen hours. Subtracting two hours off each end of this span for bad seeing still leaves ten hours a night to observe Jupiter well above the horizon.

Because ten hours is also the approximate rotation period of the Jovian cloud tops, anyone at mid-northern latitudes can observe, sketch, photograph, or videotape a full rotation of Jupiter — all in the space of one clear night.

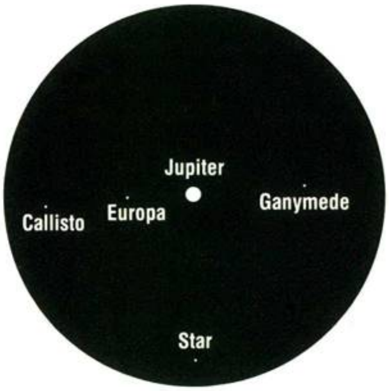
Many details in the Jovian atmosphere are well within the range of most backyard telescopes; even a 4-inch telescope, under good observing conditions, will reveal several of the alternating dark bands and light zones. Use an eyepiece that gives you high magnification while still rendering a crisp view of the planet's disk. A blue filter enhances contrast and will help you see more detail in the atmosphere.

When you first view Jupiter, pick a prominent feature near the

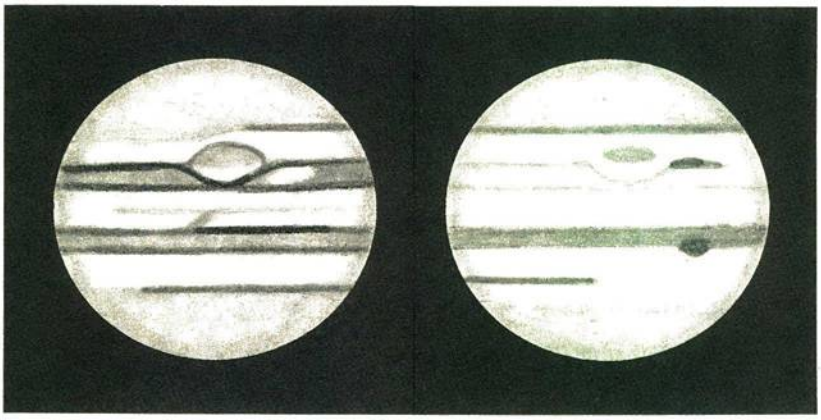
TRANSIT TIMES OF JUPITER'S GREAT RED SPOT

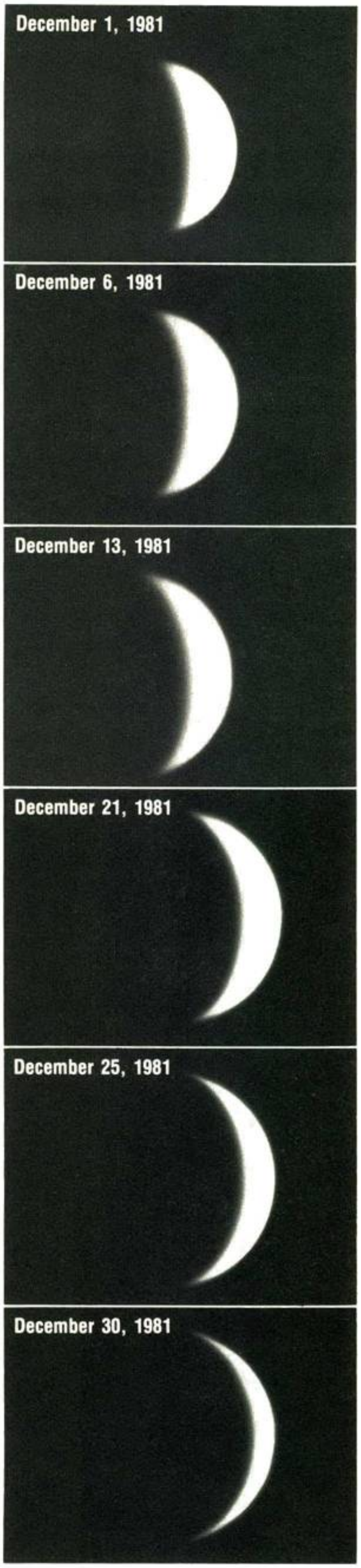
Date	Time
December 2	4:14 a.m.
December 3	12:05 a.m.
December 5	1:43 a.m.
December 7	3:21 a.m.
December 7	11:12 p.m.
December 10	12:50 a.m.
December 12	2:28 a.m.
December 14	4:06 a.m.
December 14	11:57 p.m.
December 17	1:35 a.m.
December 19	3:13 a.m.
December 19	11:04 p.m.
December 22	12:42 a.m.
December 24	2:20 a.m.
December 24	10:11 p.m.
December 26	3:58 a.m.
December 26	11:49 p.m.
December 29	1:27 a.m.
December 31	3:05 a.m.
December 31	10:56 p.m.

Transits visible throughout the United States and Canada during December. Times are in EST; subtract 1 hour to convert times to CST, 2 hours to MST, and 3 hours to PST.



JUPITER DISPLAYED a faint South Equatorial Belt in mid-1989 (below, right) compared with 1988 (below, left). Sketches by Jose Olivarez. Watch a 6th-magnitude star masquerade as an extra Jovian satellite on December 27/28 (above).





VENUS' THINNING CRESCENT and growing size highlight the planet's telescopic appearance this month. The planet will appear almost identical to the way it did in 1981, when Jean Dragesco took this sequence of photos.

meridian to follow the rest of the night. Two to three hours after the feature crosses the meridian, it will disappear off the eastern limb of the planet's disk, then approximately five hours later it will reappear on the western limb. After a total of ten hours, the feature will have returned to the point where you first saw it.

I wouldn't advise anyone to view Jupiter continuously for ten hours, but observing it every hour or so throughout the night is certainly reasonable. If you sketch Jupiter once each hour, you can take the resulting stack of sketches and make your own "rotation movie" by flipping through it rapidly.

You might try this schedule. For the first ten minutes each hour observe as much detail on Jupiter's disk as you can. Then take the next fifteen to twenty minutes to sketch what you've seen. (You can use the drawing of Jupiter on page 67, which gives the correct proportions for Jupiter's oval-shaped disk, as a template for your sketches.) Take an occasional quick trip back to the eyepiece to pinpoint the location of a detail, but remember that everything is moving fast. It's best to get the gross locations down early in each period and save the relative positions for later. Use the last thirty minutes of each hour to relax, have a snack or hot drink, or just warm up. Repeat the cycle the next hour, and keep repeating it until you or the sky give out.

As you gain experience viewing Jupiter, you'll begin to notice the delicate tendrils of dark material that extend from one belt, through a zone, to an adjacent belt. These tendrils are good benchmarks for your drawings. The table on page 63 gives the approximate times when the Great Red Spot will be visible. You may not see much of the spot, but you should see the Great Red Spot Hollow in which the spot hides.

The Galilean satellites of Jupiter offer their own special attraction late this month. Our perspective of Jupiter at opposition is only a few hundredths of a degree different from that of the Sun. Thus, we can see a satellite transit the disk of Jupiter at approximately the same time and location that the satellite's shadow crosses the disk. In effect, we can see the satellite on top of its own shadow. The best opportunity to see this rare event is on the evening of December 26/27 from about 11 p.m. to 1 a.m. EST (8 p.m. to 10 p.m. PST), when Io crosses the Jovian disk.

Another interesting event occurs the following night when Jupiter passes just south of the 6th-magnitude star HD 44927. The star is about as bright as the Galilean satellites, so on the evening of December 27/28 Jupiter appears to have a fifth bright satellite. Instead of being aligned east-west like the satellites, the star appears due north of the planet.

VENUS GOES THROUGH A PHASE

The telescopic appearance of Venus changes dramatically during December. On the 1st, Venus' disk measures 33.4" in diameter and is 36 percent illuminated, appearing like a miniature six-day-old Moon. By the 15th, Venus grows to 41.4" in diameter while its phase shrinks to just 25 percent lit, the equivalent of a five-day-old Moon. At the end of the month, Venus presents a swollen disk 53.5" across that appears like a three-day-old Moon — a slender crescent just 11 percent lit.

The 60 percent increase in Venus' apparent size this month makes the brightest planet also the largest in your telescope's eyepiece, surpassing even mighty Jupiter. Jupiter is normally the largest planet as seen from Earth — and has been for the last seventeen months — but for the two months or so near inferior conjunction Venus appears larger.

Fortunately, Venus is moving north along the ecliptic this month; thus it remains reasonably high in the sky despite the fact that it is approaching the Sun. The bright planet lies nearly 20° above the southwestern horizon forty-five minutes after sunset during December, so you can observe and record its changing size and phase with relative ease.

Use the photo sequence at left to get an idea of how quickly Venus' appearance changes near inferior conjunction. Taken in 1981 (the last time Venus had an apparition in the far southern sky), these photos show

how Venus will appear this year two calendar days earlier than in 1981. (For example, the third photo, taken on December 13, 1981, shows how Venus will appear on December 11, 1989.)

A BRIGHT THANKSGIVING COMET

The brightest comet since Halley puts on a fine show in the morning sky during November. Comet Okazaki-Levy-Rudenko is expected to peak at 3rd or 4th magnitude during the week of November 19 to 26. However, the comet should be visible to the naked eye throughout November as it makes its way southward from Bootes into Virgo.

In addition to being bright, Comet Okazaki-Levy-Rudenko could show a long tail. Because the Sun-comet-Earth angle is close to 90° during the second half of November, the comet's tail lies in the plane of the sky and not along our line of sight. Use the finder chart and the coordinates below to locate the comet. Comet Okazaki-Levy-Rudenko moves south rapidly during December and is gone from the view of observers at mid-northern latitudes after the first week of the month.

TELESCOPIC PLANETS

Mercury puts in a reasonably good appearance in the evening sky during the last half of December. Mercury is at greatest elongation on the 23rd, when it lies 20° east of the Sun. At this time Mercury sports a slightly gibbous disk measuring 6.7″ in diameter. The −0.5-magnitude planet lies 8° above the southwestern horizon thirty minutes after sunset.

Although it is slightly nearer the horizon and therefore harder to observe earlier in the month, Mercury offers an interesting target when it passes three outer planets. On December 10, Mercury passes 2° south of Uranus, whose 3″-diameter, 6th-magnitude disk will be very difficult to observe. Likewise, Neptune's 2″-diameter, 8th-magnitude disk will be impossible to see well on December 15, when Mercury passes 3° south of it. On the next night, however, Mercury passes 2.5° south of 0.5-magnitude Saturn. You should have no problem seeing the 15″-diameter ringed planet, but this could well be the last time you'll see it until Saturn pops up in the morning sky in late January.

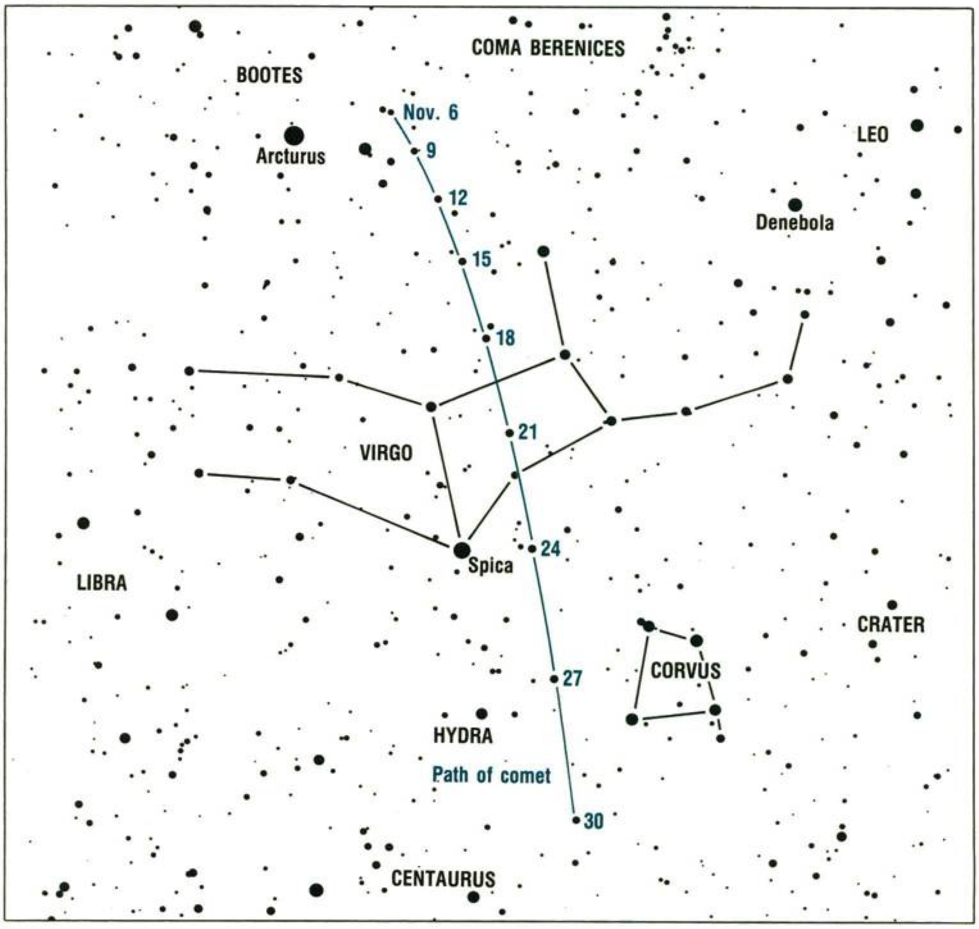
Mars continues to head south this month, and though it moves higher in the morning sky, it remains difficult to observe. The diminutive, 4″-diameter planet rises two hours before the Sun at the end of the month and shines rather dimly at magnitude 1.6.

ASTEROIDS IN THE EYEPIECE

The largest asteroid, 1 Ceres, reaches opposition on December 20. Ceres reaches a peak magnitude of 6.7, so it might be visible to the naked eye if you have excellent eyesight and observe under a very dark sky. Use the finder chart in last month's column to locate this minor planet. At opposition Ceres lies in eastern Taurus less than 10° west-northwest of Jupiter. ☐

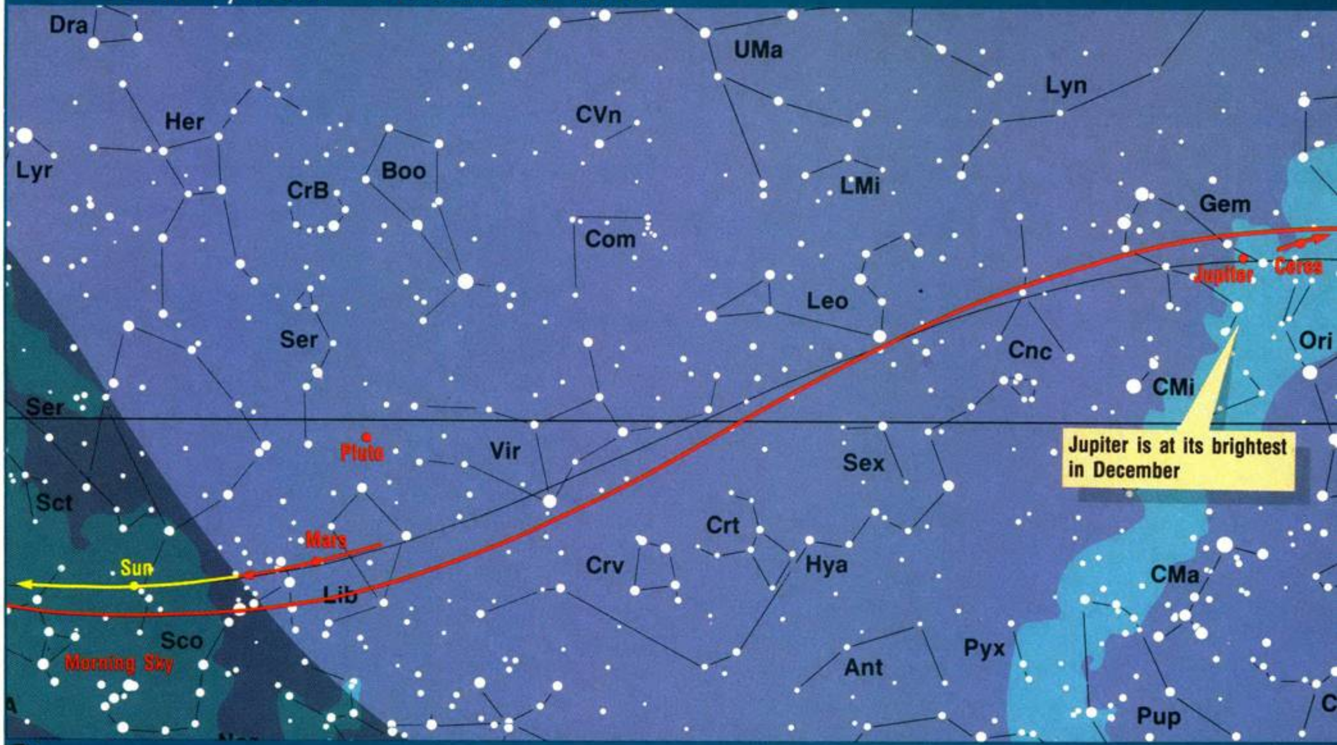
COORDINATES FOR COMET OKAZAKI-LEVY-RUDENKO

Date	R.A. (2000)	Dec.
Nov. 6	13h47.9m	21°01′
Nov. 9	13h40.9m	18°16′
Nov. 12	13h33.8m	14°43′
Nov. 15	13h26.5m	10°11′
Nov. 18	13h19.3m	4°30′
Nov. 21	13h12.2m	−2°30′
Nov. 24	13h05.2m	−10°53′
Nov. 27	12h58.3m	−20°30′
Nov. 30	12h51.3m	−30°56′



THE BRIGHTEST COMET in over three years is Comet Okazaki-Levy-Rudenko, which should reach 4th magnitude in mid- to late-November. Positions are shown at the beginning of morning twilight.

The Solar System December 1989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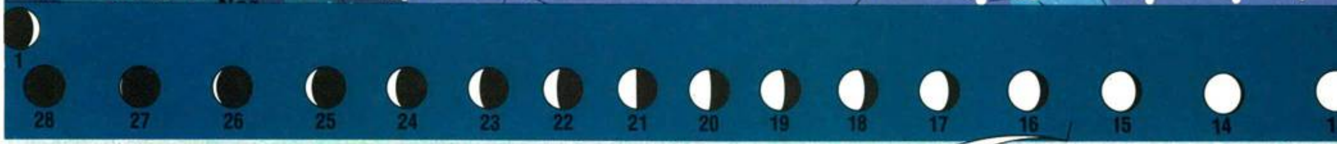
UMa
Lyn
Com
LMi
Gem
Leo
Jupiter
Ceres
Ori
Ser
Cnc
CMi
Ser
Pluto
Vir
Sex
Sct
Mars
Crt
Hya
Sun
Crv
CMa
Lib
Sco
Morning Sky
Ant
Pyx
Pup

Jupiter is at its brightest in December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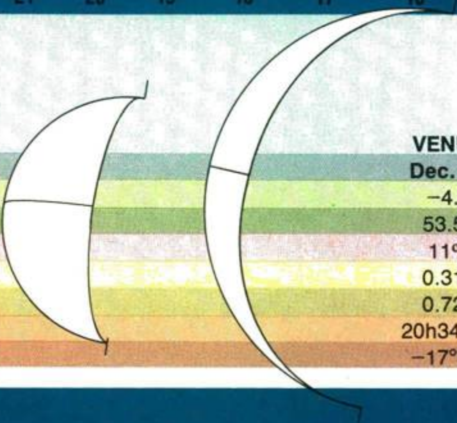
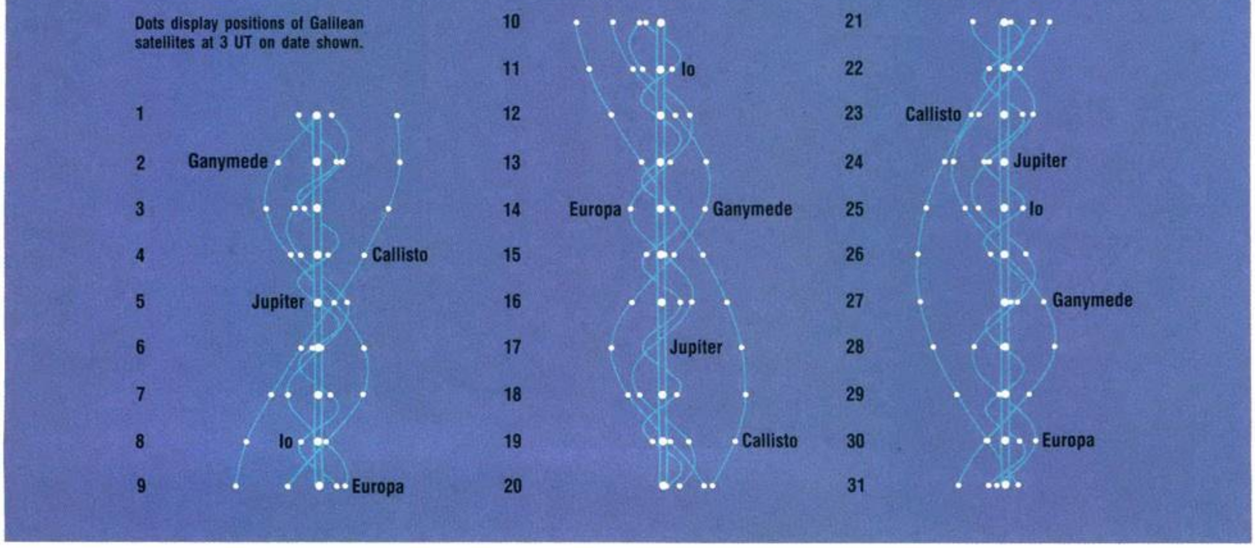
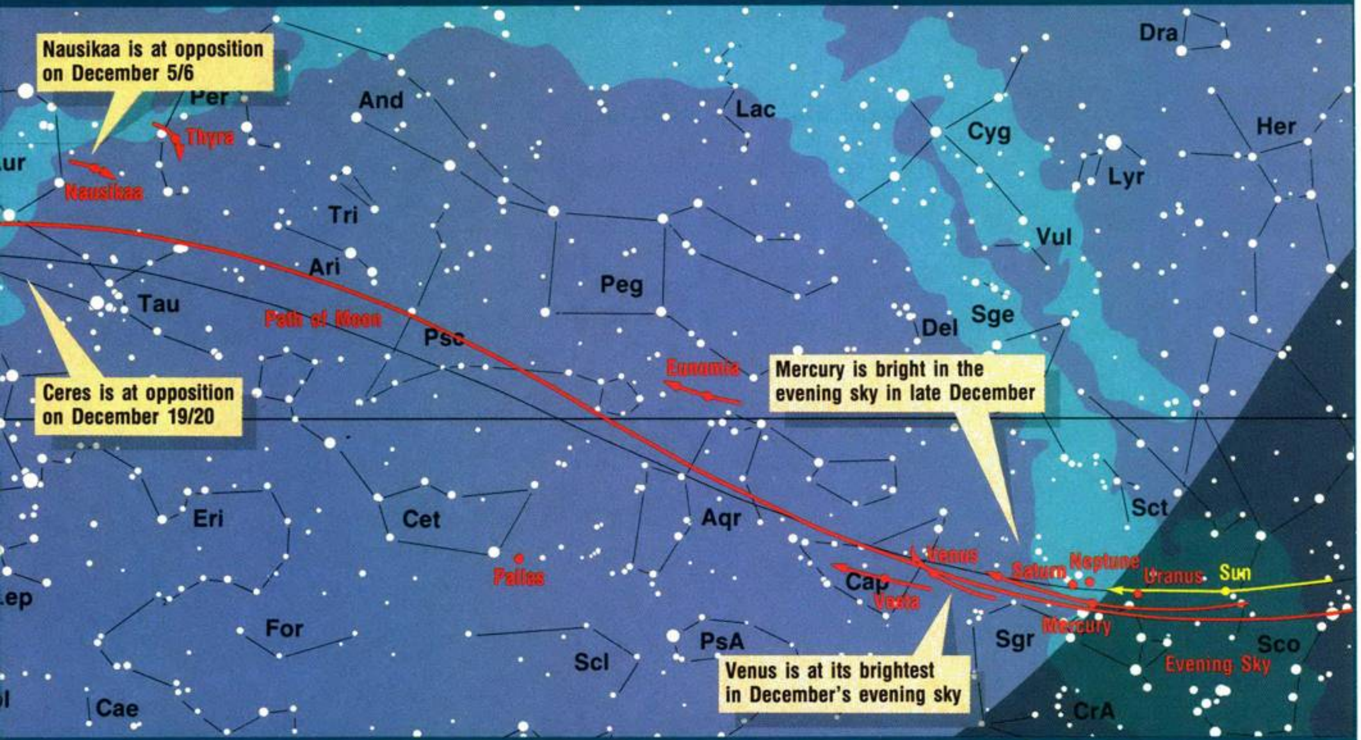


Planet	MERCURY	VENUS	VENUS	MARS
Date	Dec. 15	Dec. 1	Dec. 31	Dec. 15
Magnitude	−0.6	−4.6	−4.6	+1.6
Angular Size	5.69″	33.4″	53.5″	3.9″
Illumination	81%	36%	11%	98%
Distance (AU) from Earth	1.183	0.500	0.312	2.402
Distance (AU) from Sun	0.392	0.723	0.720	1.569
Right Ascension (2000.0)	18h48.8m	19h44.5m	20h34.0m	15h42.8m
Declination (2000.0)	−25°14′	−24°16′	−17°09′	−19°33′

Jupiter's Moons



Dots display positions of Galilean satellites at 3 UT on date shown.


ur
Per
Thyra
Nausikaa
And
Lac
Dra
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Her
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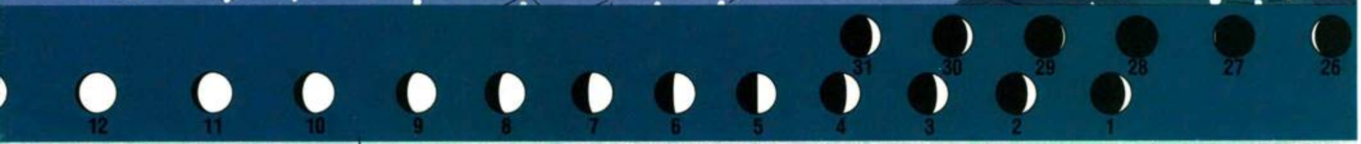
Tri
Vul
Ari
Tau
Path of Moon
Psc
Peg
Del
Sge
Eunomia
Eri
Cet
Aqr
Sct
Pallas
Venus
Saturn
Neptune
Uranus
Sun
Cap
Vesta
Mercury
ep
For
PsA
Sgr
Sco
Evening Sky
Scl
Cae
CrA

Nausikaa is at opposition on December 5/6

Ceres is at opposition on December 19/20

Mercury is bright in the evening sky in late December

Venus is at its brightest in December's evening sky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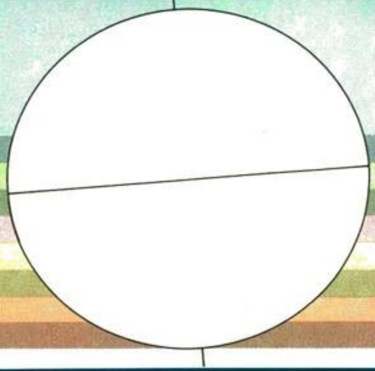
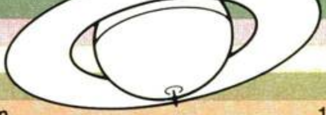
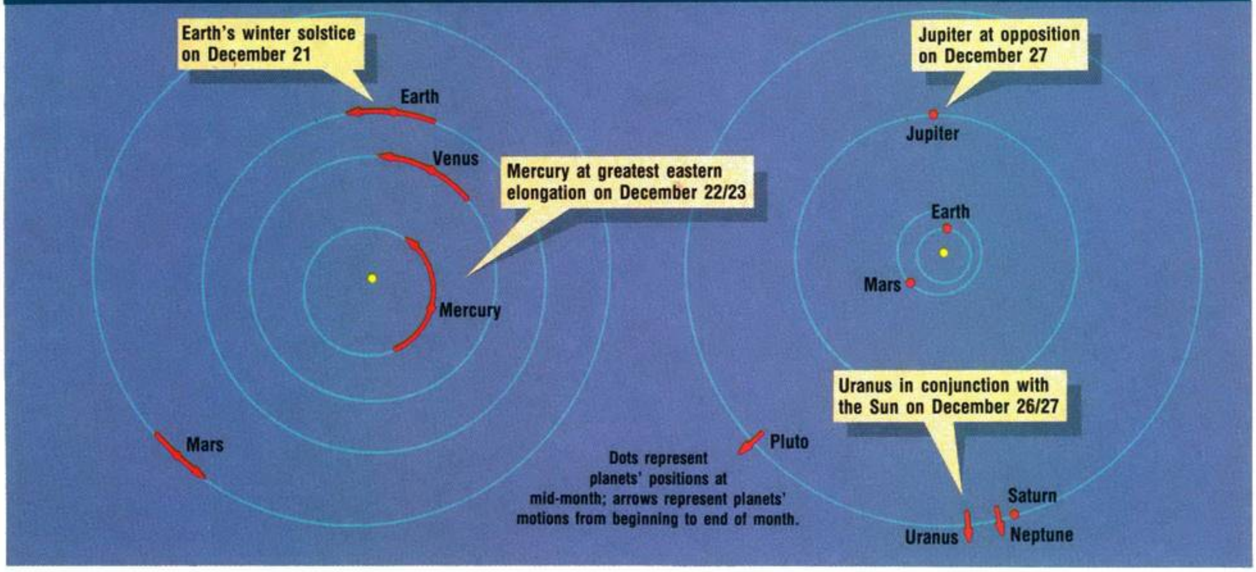




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Dec. 15	Dec. 15	Dec. 15	Dec. 15	Dec. 15
−2.7	+0.5	+5.8	+8.0	+13.8
47.0″	15.1″	3.4″	2.2″	0.1″
100%	100%	100%	100%	100%
4.186	10.943	20.340	31.143	30.414
5.145	10.028	19.377	30.211	29.656
6h33.2m	18h59.7m	18h21.3m	18h49.8m	15h14.1m
23°04′	−22°25′	−23°37′	−22°06′	−2°14′

The Planets in Their Orbits


Earth
Venus
Mercury
Mars
Jupiter
Earth
Mars
Pluto
Saturn
Uranus
Neptune

Earth's winter solstice on December 21

Mercury at greatest eastern elongation on December 22/23

Jupiter at opposition on December 27

Uranus in conjunction with the Sun on December 26/27

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

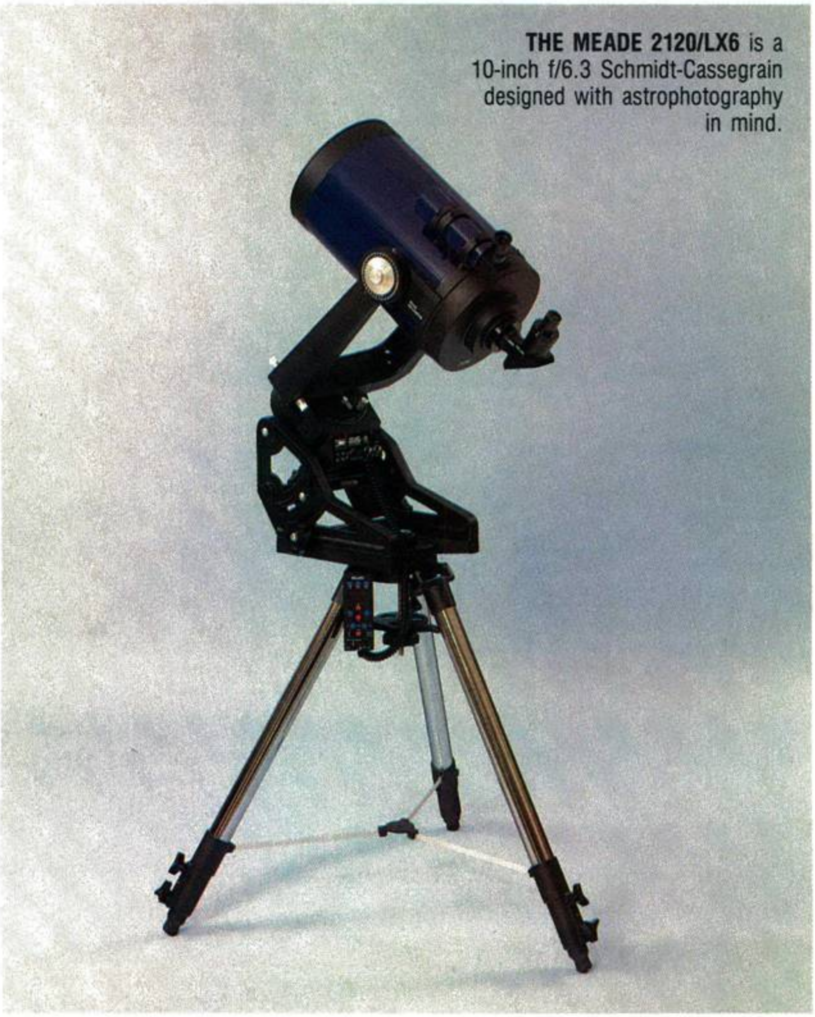
ASTRONOMY TESTS THE MEADE 2120/LX6

Our evaluation of Meade's 10-inch f/6.3 Schmidt-Cassegrain revealed a versatile scope with a few problems.

by Robert Burnham

The new fast focal ratio Schmidt-Cassegrains from Meade (the 8-inch 2080/LX6 and the 10-inch 2120/LX6) are an innovation in backyard telescopes. The telescopes have stirred considerable interest since being introduced in the fall of 1988 because with focal ratios of f/6.3, they offer rich-field performance in a type of scope whose optics are usually f/10 or slower.

Visually, f/6.3 means that with any given eyepiece, images are brighter, have lower magnification, and encompass a wider field of view. Astrophotographically, it means a sky-shooter can double the number of pictures shot per evening, because f/6.3 requires less than half the exposure time that f/10 does. (With fast hypered films, the photographer can expect to reach "sky fog" in less than ten minutes.)



THE MEADE 2120/LX6 is a 10-inch f/6.3 Schmidt-Cassegrain designed with astrophotography in mind.

We report first on erecting and aligning the telescope, then on the performance of the drive, followed by an assessment of the optics. We conclude with notes taken on various features relating to the telescope's operation.

ASTRONOMY bought a 2120/LX6 (serial #105,662, referred to as telescope 1) with the regular wedge from Shutan Camera & Video of Chicago. We tested its optics on an artificial star and discovered they were defective. We returned the optical tube assembly to Shutan and exchanged it for another from Shutan's stock (serial #106,594, telescope 2).

To broaden the basis of comparison, we asked Orion Telescope Center to loan us another tube assembly (serial #106,346, telescope 3). As a final check, we requested a 2120/LX6 (serial #106,874, telescope 4) from Meade for optical tests. We also borrowed a Superwedge (a $200 optional add-on) from Meade to check its stability. All in all, we examined four telescopes.

How does the 2120/LX6 perform? In general, it's a very good instrument, though not without flaw: the four telescopes varied in optical quality. Also the mounting, like those on many commercial telescopes, could be sturdier — although it performs adequately both for visual and astrophotographic uses.

Setting Up the Telescope

The 2120 arrives in three cardboard cartons (four, if purchased with the Superwedge). The first carton contains the optical assembly, the second has the carrying trunk, which contains the motor base, finder scope, power pack, a set of wrenches, accessories, and manual. The third carton holds the equatorial wedge and field tripod. (With a Superwedge, carton three contains only the tripod; the Superwedge comes in its own carton.) Each carton weighs 40 to 45 pounds.

The fully assembled telescope (on the regular wedge) weighs 80 pounds, with the tripod accounting for 31 pounds and the optical tube 49 pounds. With the Superwedge the entire telescope weighs 97 pounds. Any prospective buyer should note those figures; despite being compact, the 2120/LX6 is a *heavy* telescope. Erecting the 2120 requires you to lift carefully a 50-pound dead weight to slightly above waist level.

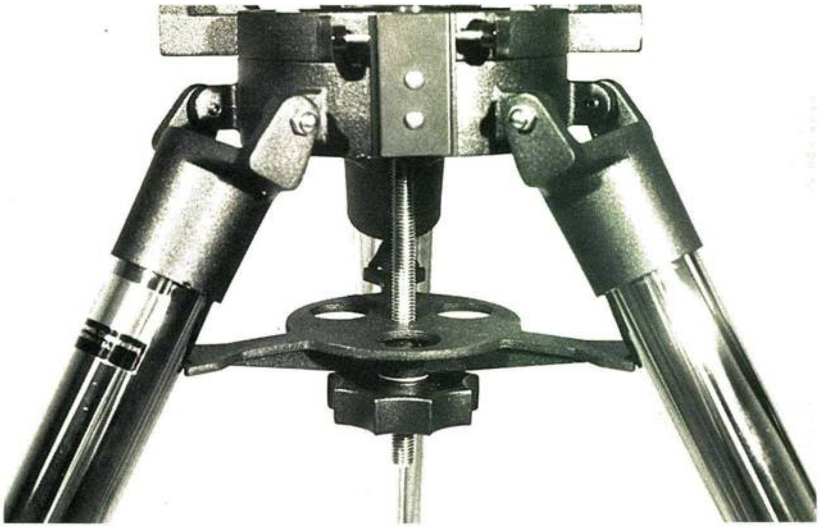
The carrying trunk for the telescope is the size of a medium footlocker. It is made of ¼-inch plywood with steel-reinforced corners, metal-reinforced edges, lid latches, and a lock. The lock worked stiffly, and we bent one of the two keys provided in unlocking it. (A prior squirt of WD-40 or graphite might have helped.) The cover, bottom, and one end of the trunk's inside have an inch of urethane foam padding. Without putting it through a destructive "torture test," we think the trunk will provide adequate protection for the telescope under normal use, though it might not be adequate if the trunk were dropped more than a foot or so.

The trunk has a handle on each end. When loaded with the telescope and the drive base, we found the trunk a heavy (nearly 60 pounds) and awkward load for one person to carry. Small adults or persons with little upper-body strength would probably find it impossible to carry it by themselves. Therefore the two handles all but force the owner to recruit a second person for carrying, which, although inconvenient, is a much safer method anyway.

The handles are plastic-on-metal fittings; the fittings attach by means of pins that pass through the plywood and are bent over. Meade cautions the owner from "overstraining" a single handle; we took this to mean not carrying the case by one handle only or subjecting it to a sudden jerk. This seems to be sensible advice.

We received two versions of the manual, one typeset (30 pages) and the other in "typewriter" format (62 pages); both appeared to contain the same material. We found the manual to be clearly written and adequately, if not profusely, illustrated. It covers the 8-inch and 10-inch models in the regular and LX3 series, and a supplement provides instructions specific to the LX6. Any novice who reads the manual carefully before unpacking and setting up the telescope should do the job correctly.

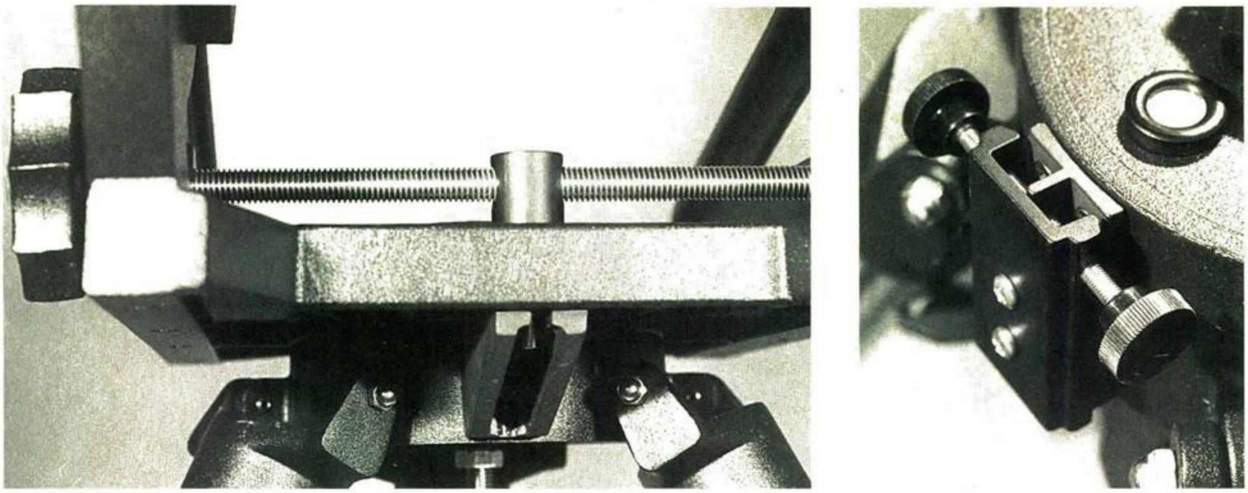
We liked several features on the tripod. Each leg extends 19 inches and has two large thumbscrews to lock the



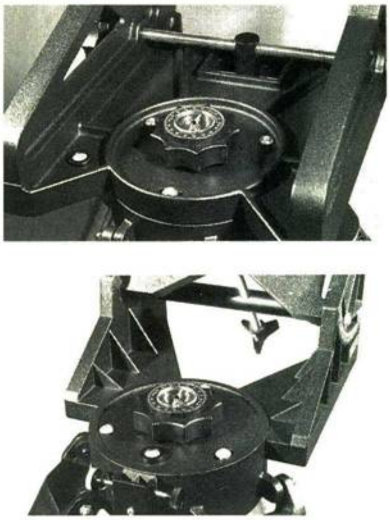
THE SPREADER AT THE TOP of the tripod locks the legs open and adds considerably to the rigidity of the mounting.

TWO LARGE THUMBSCREWS on each tripod leg assure that the 19-inch extendable section will not slip; the locks undo easily by hand.

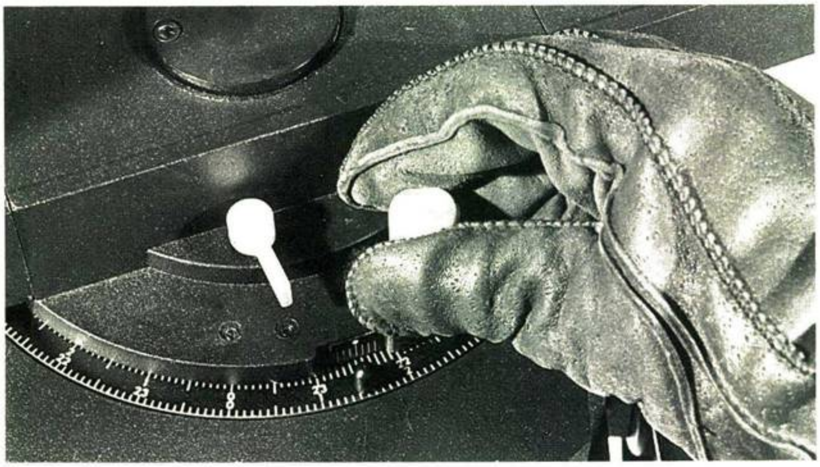
THE TRIPOD-LEG ENDS are covered with soft rubber crutch tips; despite the tips' "give" under pressure, they help damp out vibration quickly.



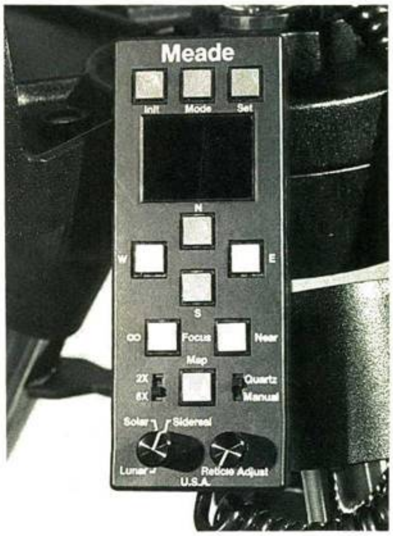
AZIMUTH ADJUSTMENTS ARE REQUIRED in polar alignment; the fittings on the Superwedge (left) are far more robust and easier to use than those on the regular wedge (right). As a result, set-up and polar alignment are faster and easier with the Superwedge.



THE SUPERWEDGE (upper) is more massive and much steadier in use than the regular wedge (lower).



THE RIGHT ASCENSION SLOW MOTION and lock can be operated by a gloved hand — a well-thought-out feature that makes cold-weather observing easier.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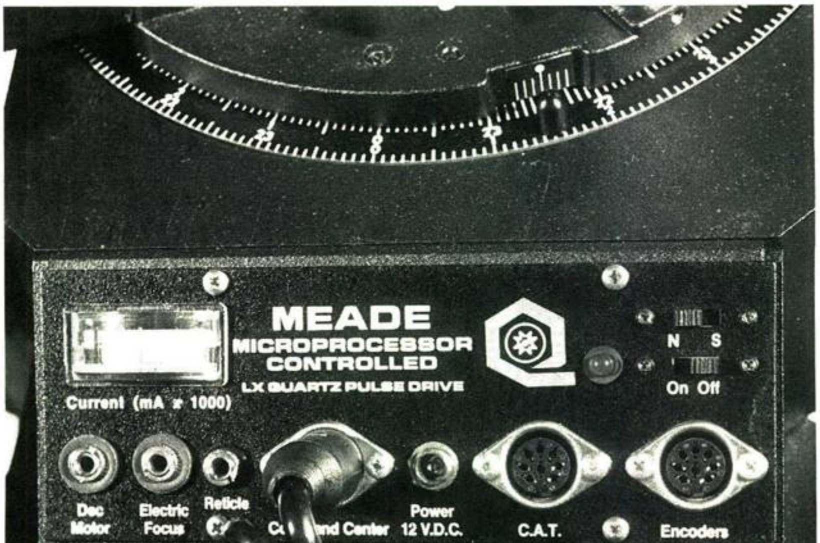
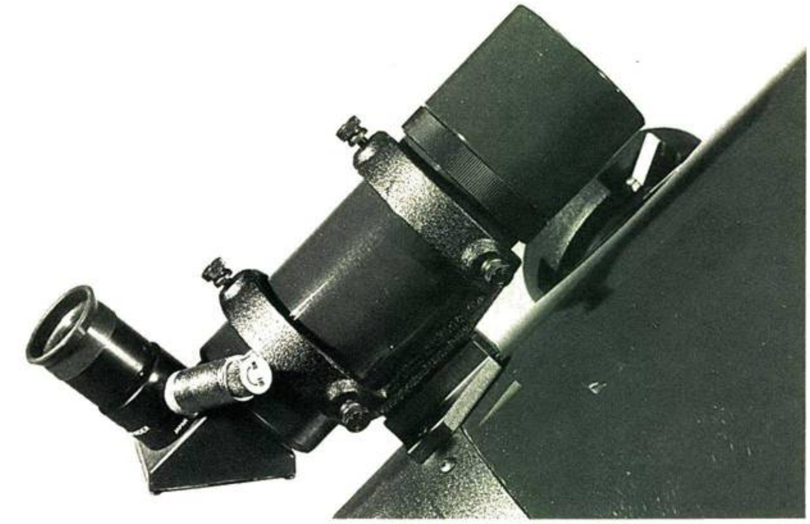
Near
Map
2X
6X
Quartz
Manual
Solar
Sidereal
Lunar
Reticle Adjust
U.S.A.

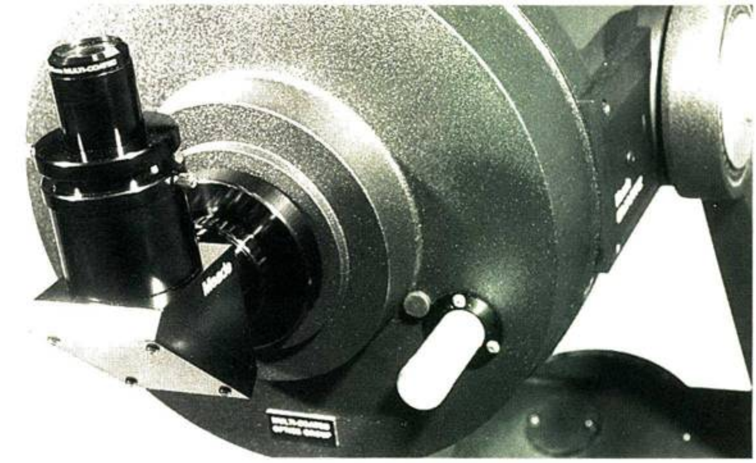
THE CONTROL PADDLE bristles with buttons, but most are useless without separately bought accessories.


MEADE
MICROPROCESSOR
CONTROLLED
LX QUARTZ PULSE DRIVE
Current (mA x 1000)
N
S
On
Off
Dec Motor
Electric Focus
Reticle
Power 12 V.D.C.
C.A.T.
Encoders

THE TELESCOPE'S DASHBOARD provides simple controls and many plug-in sockets for the optional accessories.



THE 9x60 FINDER SCOPE has enough aperture to locate many faint objects and includes a polar-alignment reticle with a dimmer switch.



THE FOCUSER AND DIAGONAL accept both 2-inch and 1¼-inch eyepieces, a useful feature. The focus knob is at the right.

extension segment (see photo on page 69). The legs themselves are braced at the top by a rigid spreader (photo, page 69), and there is a loosely jointed rod that ties the lower ends of the tripod legs together. The large nut that secures the wedge to the tripod has a small compass to help the observer locate north in the daytime or when Polaris is out of view.

With the tripod legs fully extended and the instrument pointing at the zenith, the eyepiece is 59 inches high — close to eye level for most adults. With the legs fully retracted (which is essential to achieve proper image steadiness), the eyepiece height is 42 inches and a chair or stool is needed to observe in comfort.

Each tripod leg is a chromed steel tube. The lower ends are capped with blunt hard-plastic plugs that in turn are sheathed with rubber crutch tips. The soft rubber tips add significantly to the mounting's steadiness by absorbing vibration from the metal structure. Vibrations typically damp out twice as fast with them as without them — even when the mounting is placed on soft grass.

How steady *is* the mounting? We tested the 2120 using both the regular wedge and the Superwedge, with rubber feet on and the legs retracted, on concrete and grass surfaces. For the regular wedge and a magnification of 60x, light taps on the tube damped out in 4 to 5 seconds, which seemed to be a long time to wait for the image to steady.

However, with the larger and stiffer Superwedge, the damping time for light taps averaged 2 to 3 seconds. Given this improvement, we strongly recommend the Superwedge to any 2120 buyer with interests in astrophotography or high-power viewing.

Finding the Pole

The manual describes two methods of polar alignment, one using the 9x60 finder scope, the other being the highly accurate but time-consuming star-drift method. Whichever system is used, we suspect that novice telescope owners will not get a perfect polar alignment on the first evening. Precise alignment, however, matters only in astrophotography; for casual observing a rough-and-ready alignment is adequate.

The simpler procedure outlined in the manual uses a red illuminated reticle built into the finder scope's eyepiece. A dimmer switch turns the illumination on and off and controls the level of brightness, both excellent features. A simple cardboard time-and-date dial shows where Polaris should be on the reticle; the wedge's polar elevation and azimuth are then adjusted to position Polaris there.

Before starting on polar alignment, however, the user needs to calibrate the movable declination setting circles to accurately and reliably align the scope's optical axis parallel to the mounting's polar axis. (The finder, of course, must already be aligned to the scope's optical axis.) The manual, however, doesn't mention or explain the process — a deficiency that needs fixing. The declination setting circles have divisions at 1° intervals; in right ascension the divisions are at 5 minute intervals.

The regular wedge and Superwedge both adjust easily in polar altitude. The regular wedge has a latitude scale with divisions at 1° intervals, the Super has the same plus a vernier. You loosen the lock bolts and turn a large knob attached to a threaded rod that pushes against the bottom of the drive base. When the elevation is correct according to the reticle, you retighten the lock bolts.

Azimuth adjustment is slightly more complicated. Both wedges attach to the tripod head by means of a large nut in the center and three bolts in curved slots, which afford about 15° of rotation travel. To make small adjustments in azimuth, you loosen the three bolts and the large nut.

To make azimuth adjustments with the regular wedge, you turn a small knurled knob that pushes against a small tangent arm (see photo on page 70). The Superwedge also uses a tangent arm, but the arm is far more robust and the hand-sized knobs are much easier to grasp, especially while wearing gloves. We found that with a little practice, erecting the telescope, including performing the simple polar alignment, takes about fifteen minutes; knock-down takes about ten.

We checked the drives on telescopes 2 and 4 by centering Vega in a 3.8mm eyepiece (421x). Tracking the star for more than an hour told us that the drives on both telescopes had similar periodic errors — about 25 to 30 arcseconds in size. The rate of the error was slow enough to be easily correctable with the controls on the paddle, and we think that the performance of both drives was adequate for astrophotography. However, serious astrophotography would require the purchase of an additional off-axis guide unit.

The drive control paddle provides several ways to adjust the tracking rate and correct for errors in the drive. You can continuously vary the driving rate by adjusting a knob; settings for sidereal, solar, and lunar rates are marked. You can also drive the scope east or west at two or eight times the sidereal rate. (This functions as your main control for guiding.) While the eight-times rate isn't really fast enough to be called "slewing," it is handy for bringing an object located at one edge of the field of view into the center. The corrections turned on and off smoothly, without jerkiness.

None of our test telescopes were equipped with the optional declination or electric focus motors; the manual focus control knob turned smoothly on all the examples we tested, although there was a focus shift (see below). We think that reaching over to operate the declination slow motion, which has a total travel of 5°, might be difficult if the user has short arms or is standing close to the focuser. Because of this, we suggest that buyers who intend to do a lot of guided astrophotography spend the extra money for the optional declination motor drive, which is controlled from the paddle.

Scoping Out the Optics

ASTRONOMY's optical rating scale runs from A (best) to E (worst). An A rating indicates that a telescope gives an excellent image. To earn this rating, the image of a star must approximate a perfect Airy disk. An A-rated telescope can be called "diffraction-limited," because diffraction alone is what controls the size of a star's image.

A score of B means that a star's disk is larger than the Airy disk, but not more than twice the area of a perfect Airy disk. We feel that a B-rated telescope would satisfy most observers.

A rating of C indicates that the telescope produces a stellar blur circle with twice the diameter of the Airy disk (that is, four times its area). The blur circle may be enlarged or made slightly noncircular due to optical problems such as spherical or chromatic aberration, astigmatism, or zonal errors. Star images can also be distorted by mechanical defects such as improper assembly or optics that are deformed by their mounting cells. In our opinion, a score of C represents the minimum acceptable performance for an astronomical telescope.

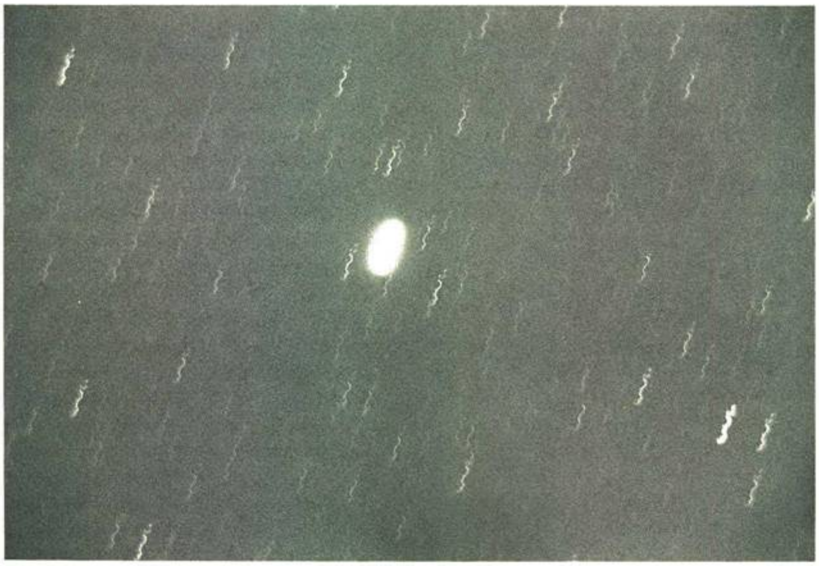
Telescopes with scores of D and E have still larger stellar blur circles and/or visible aberrations that betray progressively larger defects. An E instrument is close to unusable.

Of the four telescopes we examined, three met our minimum performance criteria. The best of them was telescope 4 — the loaner from Meade — which we rated as a B. It missed the top score because its stellar blur circle was about 1.5 times larger than the Airy disk of a perfect 10-inch telescope. While we could resolve Epsilon Lyrae with it, the star images were not crisp and clean. Furthermore, although we could see Saturn's Cassini division, the planet's image was soft overall, despite fairly good seeing.

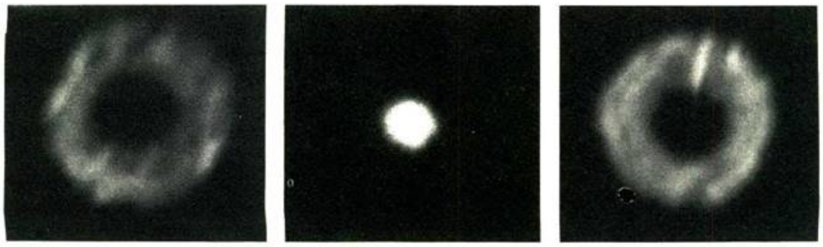
Telescope 1 rated E and was immediately exchanged by the dealer; telescopes 2 and 3 both rated C, because they showed noticeably enlarged star images that were slightly asymmetric. The dominant optical problem in telescopes 2 and 3 was spherical aberration.

How important is top-notch optical quality? This depends on your intended uses. For low-power viewing (which the f/6.3 focal ratio implicitly encourages), a high rating isn't absolutely critical. Both C telescopes would perform acceptably for low power deep-sky viewing or for astrophotography at f/6.3. However, if you want to enjoy high-power views of the planets, double stars, the Moon, or of deep-sky objects like globular clusters, we recommend a telescope with a performance rating of B or better.

Because of the variation we found in optical quality, we suggest that a buyer be prepared to check the telescope's optics using the simple set of tests described in "How to Star Test Your Telescope" by Dick Suiter in the April 1983 issue. Anyone who has bought a new telescope should perform these tests as soon as possible after taking delivery of the instrument. If the optics prove unsatisfactory, the telescope can be exchanged through



ALBIREO IS THE BRIGHT BLOB in this photo taken at prime focus with telescope 4. The polar axis was purposely misaligned so that star trails would show the drive error. Note also the enlarged star images in the corners of the field.



VEGA inside, at, and outside focus; the streaks are due to seeing, not mirror defects.

2120/LX6

10-inch f/6.3 Schmidt-Cassegrain telescope. Supplied with enhanced reflectivity coatings (mirrors) and antireflection coating (corrector plate), tripod, equatorial wedge and compass, drive, drive corrector control paddle, 9x60 right-angle finder with illuminated reticle, 26mm Super-Plossl 1¼-inch eyepiece, 2-inch mirror star diagonal (with insert adaptor for 1¼-inch eyepieces), AC adaptor, 12-volt power pickup for car cigarette lighter, Allen wrench set, carrying trunk.

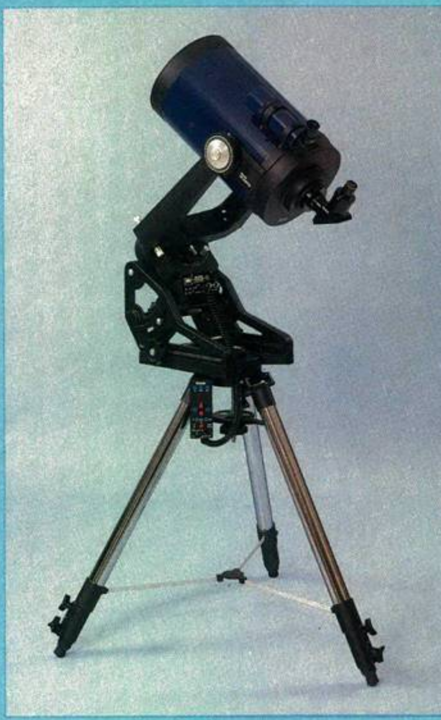
Manufacturer: Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, California 92626; (714) 556-2291.

List price: $6,400 (regular wedge); $7,400 (Superwedge). Prices from dealers are typically discounted more than 50 percent.

Pros: Fast f/ratio, wide fields of view at low power, designed for astrophotography, optional extra-heavy-duty Superwedge.

Cons: Inconsistent scope-to-scope optical quality, tripod less steady than desirable, carrying trunk requires careful handling.

Summary: A good instrument for beginning astrophotography. Heavy-duty Superwedge makes small adjustments in polar alignment easy and adds necessary steadiness. Drives sampled had easily corrected periodic errors.



the dealer where it was bought. If the return period has expired, the telescope should go back to the manufacturer.

We asked Meade Instruments what course of action they take when a customer is dissatisfied with the optical performance of a Meade telescope. We were told that after attempting to resolve any problems by phone or letter, Meade will adjust, refigure, or replace the optics on any telescope they produce, no matter when purchased, if the original owner is unhappy with the optics and returns the instrument to the company.

User's Notebook

Focus shift. Schmidt-Cassegrains focus by moving the main mirror; in nearly all SCTs this introduces a certain amount of image shift when you turn the focus knob one way and then the other. The first telescope we bought (the one returned because of poor optics) had the least focal shift: about 20 arcseconds. Its replacement (telescope 2) had the most, about 120 arcseconds. Telescope 3 had about 30 arcseconds' shift, and telescope 4 had a 40 arcsecond shift.

Any image shift is undesirable, but if it is 60 arcseconds or more, focusing becomes difficult. Because the normal way to focus is to rock back and forth through focus, narrowing the overshoot each time, a large shift makes this an exasperating process. Because the amount of shift will vary from one telescope to the next due to manufacturing idiosyncrasies, if you have the opportunity to examine several instruments in a telescope store before choosing one, then do so.

Astrophotographic image quality. We took test photos of Vega and the region around Albireo, which were both high in the sky (see photos on page 72). We found that the images were sharpest in a half-degree-diameter circle centered on the middle of the 35mm frame. The images outside this circle looked soft to us. Stars in the extreme corners of the Albireo photo had faint "tails" about 0.3mm long. On an 8x10 enlargement, these would be about ⅛-inch long.

Collimation. The 2120/LX6, like any telescope, needs to be kept in good collimation. We found that it was necessary to touch up the collimation — no big chore, given the clear instructions in the manual — whenever the scope had been transported. It is also worth rechecking the collimation when the telescope has cooled down to match the ambient temperature.

Slow motions and locks. We were pleased that both the slow motions and their locks were easy to manipulate while wearing gloves. The control paddle was a little more awkward because the buttons are only a centimeter square and placed ¾ inch apart. But as long as the gloves were not very stiff or thick, we could reliably hit the intended button and operate it properly.

Star diagonal. The diagonal is designed to accommodate both 2-inch and 1¼-inch eyepieces (the latter by means of a removable adaptor). Two small thumbscrews tighten to secure the adaptor and the eyepiece. The diagonal attaches by means of a threaded collar that screws on to the back end of the telescope. We found it took a little practice to get the collar tight enough so that the diagonal would not abruptly slip and rotate under casual handling in normal use.

Portability. The 2120 breaks down into two main pieces for transport: the tube and drive base, and the tripod and wedge (regular or Super). While both pieces are heavy, they are not unnecessarily bulky considering the telescope's aperture. They fit quite well into a Toyota Tercel, for example, and we judge most adults could lift the parts in and out fairly easily.

The 2120/LX6 drive base runs on 12 volts DC supplied by a transformer with a 25-foot cord. An attachment to take power from your car's cigarette lighter is also included. This arrangement keeps the voltage on-board the telescope to 12 volts DC, instead of 110 volts AC, which is a good safety feature.

We were pleased with many of the 2120/LX6's features — its fine low-power views of wide fields, its smoothly working drive, the glove-workable slow motions, and the greater stability of the Superwedge, to name a few. Although the 10-inch is considerably bulkier than an 8-inch SCT, it is still an easy telescope to use, and it would be a good scope for getting into astrophotography.

We were bothered by the variation in optical quality in the units we examined. But based on such a small sample, ASTRONOMY cannot judge how good a telescope you would receive if you bought one. We recommend, as we do with *all* new telescope purchases, that the buyer immediately check the optical quality of the telescope. □

WILL IT BE CLEAR TONIGHT?

You don't need to be a weatherman to figure out whether tonight's sky will be cloudy or clear.

by James Moeller

Everything is ready; it looks like it's going to be a beautiful night. You've planned ahead to insure that you have everything you'll need. Even the meteorologist on television is predicting clear skies! Upon arriving at your observing site, however, you discover a large sheet of clouds rapidly moving in and obscuring the skies.

Does this sound familiar? It happens to every amateur astronomer sooner or later. Yet with some very basic weather-wise knowledge, it can be avoided. There is much merit in the sky lore that farmers and mariners have perfected over the centuries, yet in today's electronic, satellite-scrutinized world, some of these basics have been forgotten. You don't need a barometer, hygrometer, anemometer, thermometer, or any other "ometer" to predict immediate sky conditions. With only your eyes and a sense of direction, you can make amazingly accurate predictions about the potential cloud cover and atmospheric stillness over the next twenty-four-hour period.

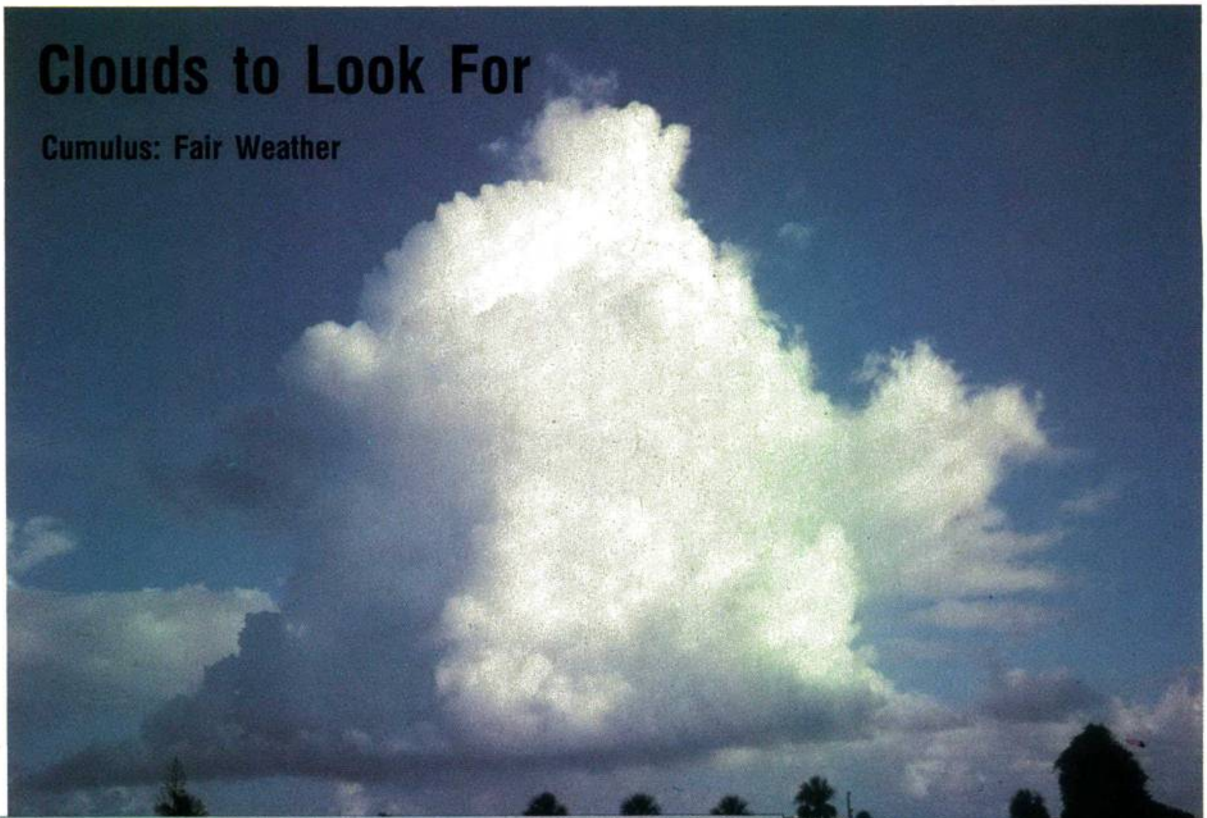
Where Clouds Come From

The goal is not to make week-long weather predictions, but to find out if clouds will spoil your evening's observing session. In order to do this, it is necessary to have some idea of what generates clouds.

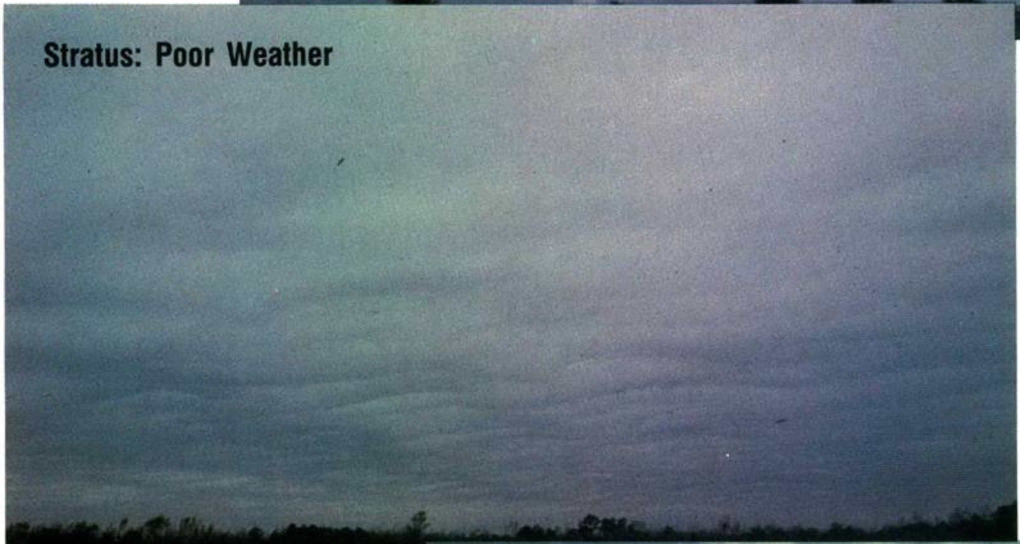
In short, clouds are composed of fine water droplets. The cloud droplets condense on to minuscule dust particles called condensation nuclei, which are simply any of the ubiquitous dust particles found in even the purest arctic air. The amount of condensation nuclei varies from one region to the next, but there are typically between a thousand to a million

ENCROACHING CLOUDS that might spoil a night's observing can often be predicted if you know how to interpret certain weather signs.

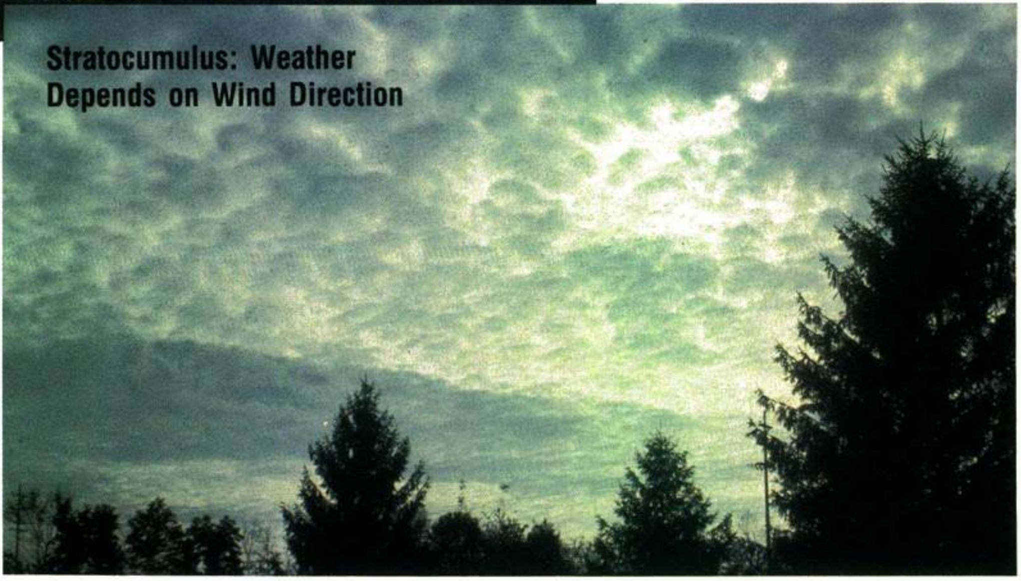
Clouds to Look For



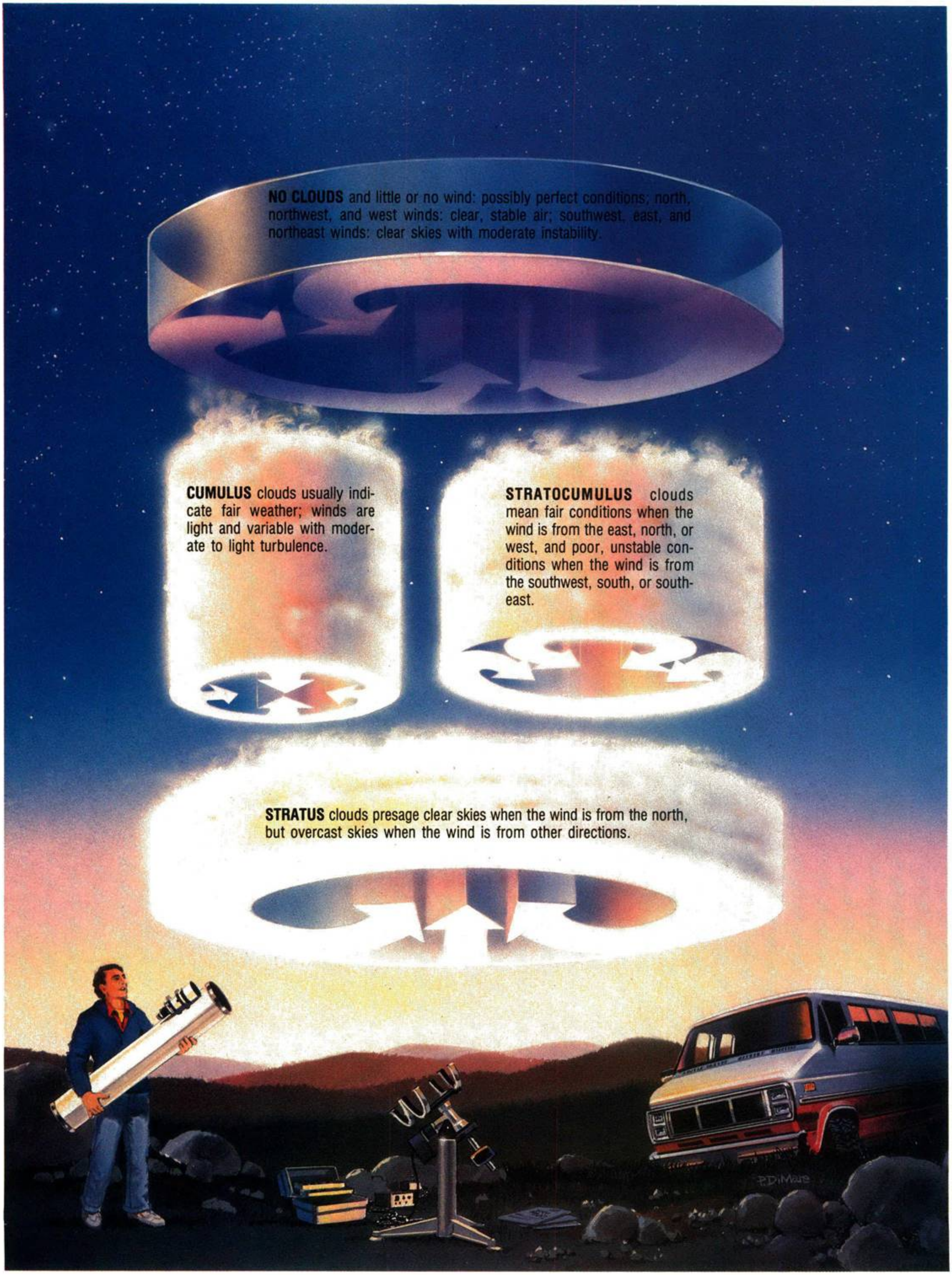
Cumulus: Fair Weather



Stratus: Poor Weather



Stratocumulus: Weather Depends on Wind Direction



NO CLOUDS and little or no wind: possibly perfect conditions; north, northwest, and west winds: clear, stable air; southwest, east, and northeast winds: clear skies with moderate instability.

CUMULUS clouds usually indicate fair weather; winds are light and variable with moderate to light turbulence.

STRATOCUMULUS clouds mean fair conditions when the wind is from the east, north, or west, and poor, unstable conditions when the wind is from the southwest, south, or southeast.

STRATUS clouds presage clear skies when the wind is from the north, but overcast skies when the wind is from other directions.

nuclei in every cubic inch of air. The nuclei's average size is about a thousandth of an inch in diameter.

Condensation can't occur, however, without a third factor coming into play: temperature. Warm, moist air must be cooled enough so that water vapor condenses into droplets, much like the droplets that form on the outside of a cold soda can in the summer. Air is cooled either when it radiates away heat, as it does at night (causing dew to form on corrector plates), or when it is lifted to a higher altitude. Whenever condensation occurs in a rising parcel of air that has the same temperature, pressure, density, and humidity throughout, a cloud forms.

When the air is cooled even further, these water droplets increase in size until they are heavy enough to fall in the form of rain or snow. The approach of a cold front usually cools the air sufficiently to generate not only clouds, but plenty of precipitation too. In this situation the air behind the cold front is cooler than the air in front of it. The cold air sinks because it is more dense and therefore pushes under the warmer air. This raises the warm air, which causes it to cool and form clouds. Because warm air can hold more moisture than cold air, these conditions usually mean some precipitation will fall. In the spring severe thunderstorms may form.

The air in a cold front is usually dry and therefore not conducive to cloud formation. Although stratus clouds sometimes accompany the front, the lack of moisture behind the front means that the sky will clear, usually within a few hours. The mixing of the warm and cool air masses, however, often causes turbulent conditions to prevail for several hours afterward.

When a warm front approaches your area, the warm air rises over the heavier, colder air near the surface and is cooled as it moves upward. This is a much slower process and can generate sheets of clouds and rain that can hang on for days.

Certain types of clouds can tell you a lot about what to expect in the sky because they are associated with certain types of weather. The most common type are cumulus clouds, the clouds we see in the summer that resemble large, puffy cotton balls. Meteorologists often refer to them as "fair-weather cumulus" because they usually tell of fair weather with no abrupt changes in the near future. Be sure, however, to note if they appear to be building higher in the sky, especially in late afternoon. This often presages strong thunderstorms. Such thunderstorms are usually brief, and because they are heat-driven, subside by nightfall.

Low clouds that look like solid sheets with little or no apparent surface detail are stratus clouds, so called because they are layered or stratified. Stratus clouds are associated with warm fronts, which almost always bring on high humidity levels with some form of precipitation. Stratus clouds may linger for hours or days.

Occasionally, cumulus and stratus clouds mix, producing stratocumulus clouds. Usually, you see these clouds gathering before storms. They have some visible surface details, so their height can be estimated. If you look in the direction of your prevailing winds, you may even notice that they appear to be getting lower, like stratus clouds. Should this be the case, precipitation is almost guaranteed.

Know Which Way the Wind Blows

In addition to cloud types, wind direction is also a key factor in estimating sky conditions. In the northern temperate zone of the Western Hemisphere, the prevailing wind direction is from southwest to northeast. A wind that comes from the west or northwest usually means there will be little change in the weather.

"Some are weatherwise; some are otherwise."
— Ben Franklin, *Poor Richard's Almanac, 1735*

The one exception to this rule is if you have a large body of water to either your northwest or west, in which case you can count on having more clouds than you otherwise might. This phenomenon is called the "lake effect." When air moves over an open body of water, it causes some of the water to evaporate. The influx of moisture into the atmosphere can generate clouds as far as 200 miles downwind from the body of water.

A breeze from the southwest will usually not obscure your skies immediately, but it will warm things up a bit, as well as increase the humidity. Within a day or two, however, you will begin to see clouds approaching from the southwest, and sometimes rain will follow.

There is a very easy way to determine if your skies will be fair or cloudy. Go outdoors and stand with your back to the wind. Generally speaking, low pressure will be on your left and high pressure will be on your right. With a high-pressure system (fair weather, clear skies), the winds circulate in a clockwise direction and come out of the northwest. With a low-pressure system (deteriorating conditions), the winds circulate in a counterclockwise direction and so come out of the south. Thus, a wind blowing south to northeast usually means increasing clouds; the closer the wind gets to being from the northeast, the sooner clouds will move in.

Putting It All Together

Making predictions of sky conditions is relatively simple as long as you know the basic rules of what goes into making the weather happen. Only two other conditions need to be mentioned: no wind and variable winds. These two are the best types to have, especially if a cold front has swept through your area the day before. The sky should be quite clear, and because there is little or no wind, turbulence shouldn't be a problem.

This lack of wind turbulence results from equivalent thermal conditions on the ground and aloft and explains why viewing conditions are sometimes better in the winter than in the summer. During the summer the ground is heated by the Sun, and when there are no clouds, we experience "radiational cooling" at night. As the ground gives up its heat, currents of warm air rise, which in turn agitate the atmosphere and make objects appear to boil in the telescope.

This problem can be minimized if you observe in the late hours from a grassy area (which cools down faster than concrete or blacktop), but then you often have to contend with heavy dew. During the winter, however, the Earth's surface isn't heated enough during the day to have much radiational cooling occur at night. Consequently, the air overhead isn't stirred up by rising air currents and is much calmer. The best time to begin observing in the winter is about two hours after sunset.

"Some are weather-wise; some are otherwise," Ben Franklin wrote in *Poor Richard's Almanac* in 1735. Amateur astronomers often have their plans foiled by the weather but fail to use it to their advantage. Using the described methods, I have been able to maintain a 90 percent accuracy rate in my predictions, which means that most of the time I can predict when my skies will be clear or cloudy. In the long run it means less disappointment and more observing. ☐

James Moeller is an amateur astronomer who lives in Kirkville, New York. He has been an amateur meteorologist for ten years.

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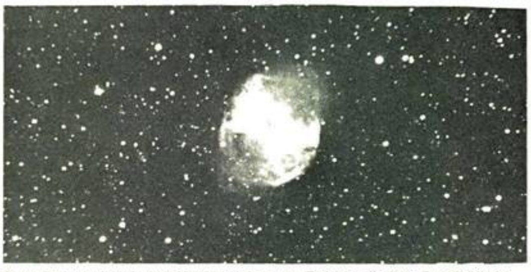

The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

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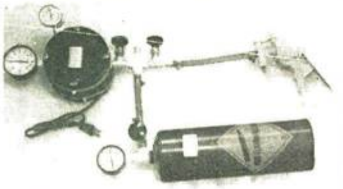

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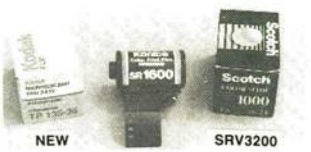

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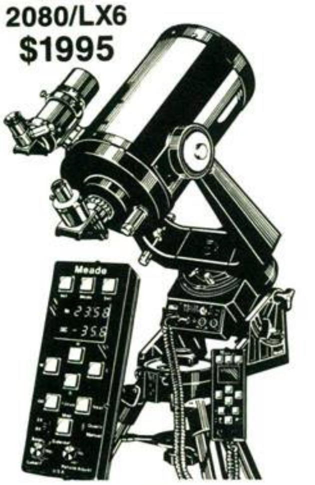

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THE SUMMER ECLIPSE OF THE MOON

The spectacular total lunar eclipse on August 16 was captured by photographers across the Western Hemisphere.

by David J. Eicher

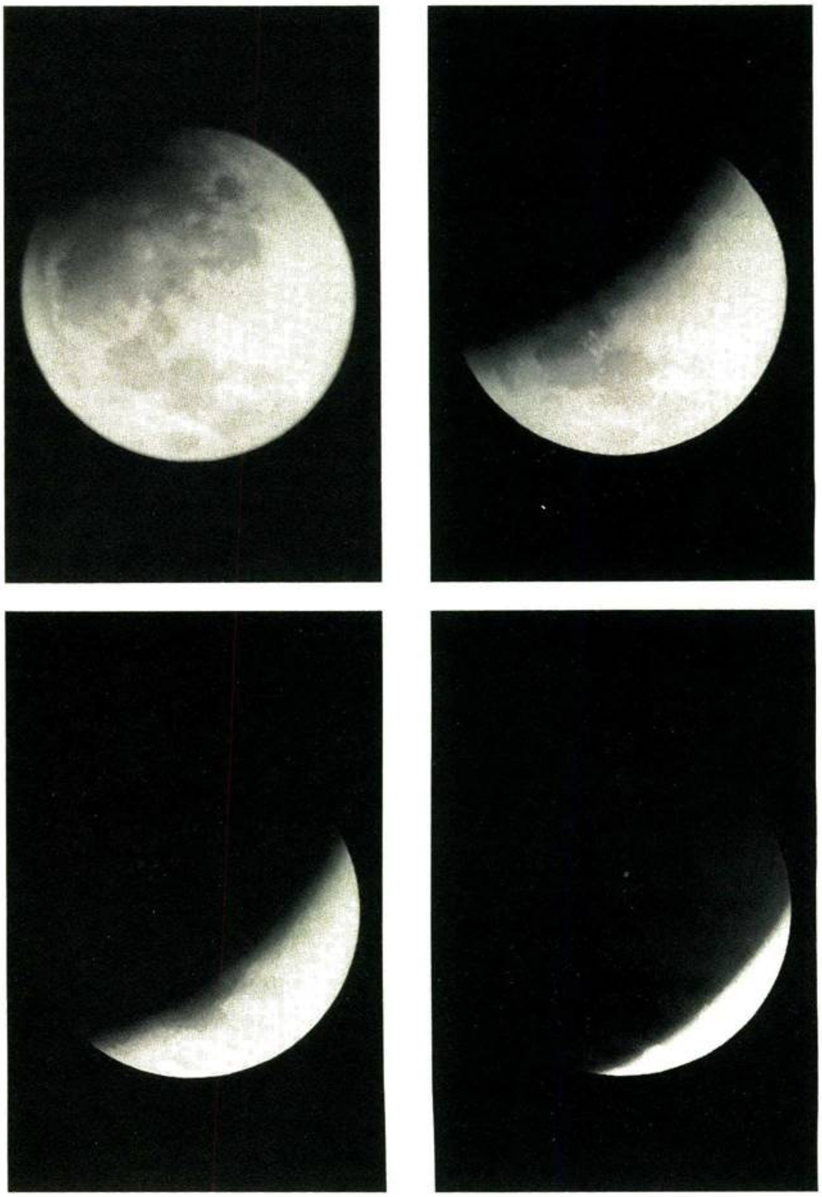
It came up over the countryside like the star of the show. On the warm, humid evening of August 16, a rusty orange Full Moon rose above the horizon and then put on one of nature's most spectacular light shows — a total lunar eclipse. Observers across the country watched the Moon and at 9:21 p.m. EDT saw Earth's shadow begin to slowly move across the face of the Moon.

The entire eclipse was visible from the eastern and midwestern United States, South America, western Europe, and western Africa. Observers in the western United States saw the already eclipsed Moon rise and watched as Earth's shadow slowly receded. Five-and-a-half hours after the eclipse started, the Moon returned to its normal self.

Because the Moon was relatively distant at the time, the total phase lasted 96 minutes, only 11 minutes short of the longest possible duration. "It was the nicest lunar eclipse I can remember for many years," said George W. Gliba, secretary of Maryland's Goddard Space Flight Center Astronomy Club. Gliba noted that the eclipse was an especially dark one, with the Moon appearing like an eye winking in a sea of darkness.

In Burlington, Ontario, Clive Gibbons observed the eclipse and thought the Moon had a warm glow, especially in the penumbral stages. "During the umbral stages, the Moon appeared strongly coppery red, more so than the eclipse in July 1982," Gibbons reported. In many areas, observers remarked that when the Moon exited the umbral phase, it appeared like a giant eyeball suspended in the sky.

Indeed, more so than other recent sky events, this August's lunar eclipse attracted thousands of fascinated viewers, all of whom came away feeling a little bit better than they did before. □



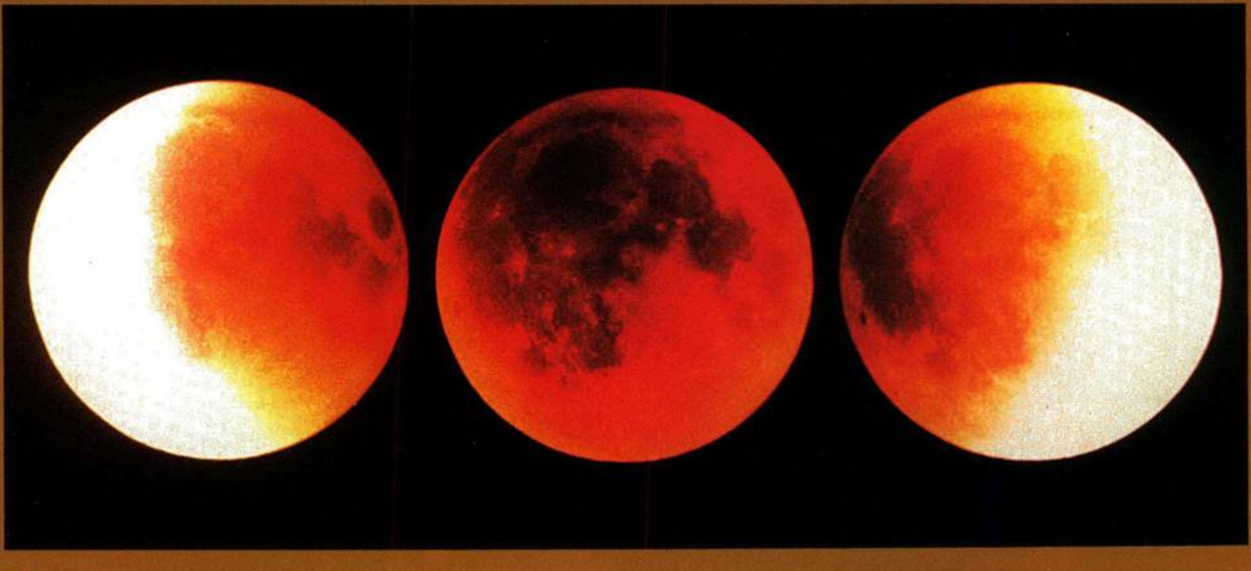
THE MOON SLIPS INTO ECLIPSE as Earth's penumbral shadow works its way across the lunar surface. The photographs show the Moon at 10:20, 10:45, 11:00, and 11:10 p.m. EDT (shortly before totality). Photos by Dale K. Bonges. Opposite page: The eclipse shortly after totality ended. Photograph by Eric Bunn using a 6.8-inch refractor at f/9.3, Ektar 125 film, and a 10-second exposure.

A GALLERY OF ECLIPSED MOONS

Observers in the western United States saw the eclipsed Moon rise out of the horizon murk and slowly brighten from dull orange to stark white. In El Cajon, California, Jerry Schad made a multiple exposure showing the Moon's progress throughout the last half of the eclipse (opposite page). Schad used a 35mm lens, Kodachrome 64 film, and made exposures at 10-minute intervals between 8:10 p.m. and 10:00 p.m. PDT.

Shortly before and after totality, the Moon was at its prettiest, giving viewers eerie glows ranging from dull blue to soft lavender to rust-bucket red. Bill and Sally Fletcher of Malibu, California, recorded the Moon just after totality (below) with a 16-inch f/4.5 reflector and VRG-1000 film.

Jim Rouse shot the eclipse from Greenville, South Carolina, and made a striking composite of 30-second exposures (bottom). Rouse used a 4-inch f/9.8 refractor, recording the Moon at 10:20, 11:07, and 11:56 p.m. EDT. Single exposures made by Mark Payne-Gill in Piddington, Buckinghamshire, England (left) show the eclipse before, during, and after totality. The central photo shows the star 44 Capricorni near the Moon's limb. Payne-Gill used a 12-inch f/5.2 reflector, Fujichrome 100D film, and 8-second exposures.



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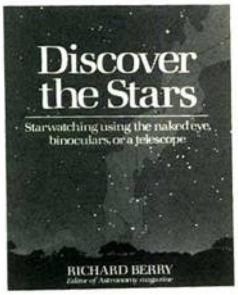
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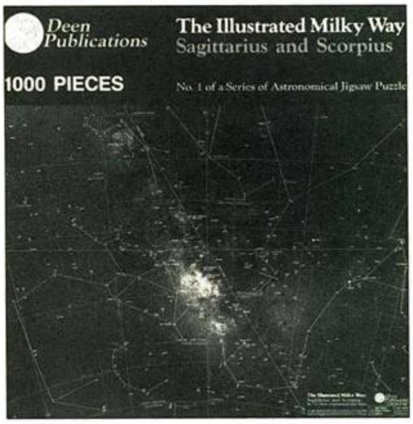
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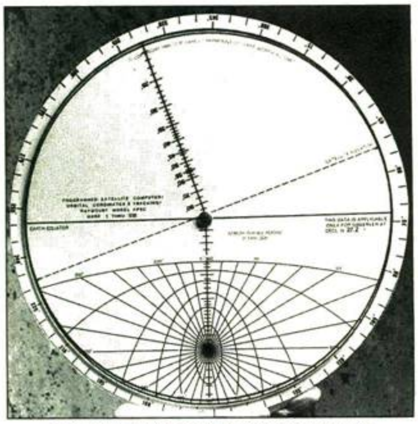

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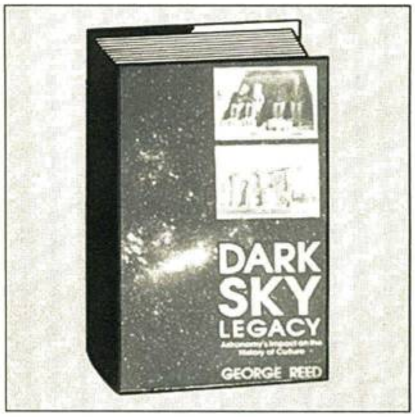

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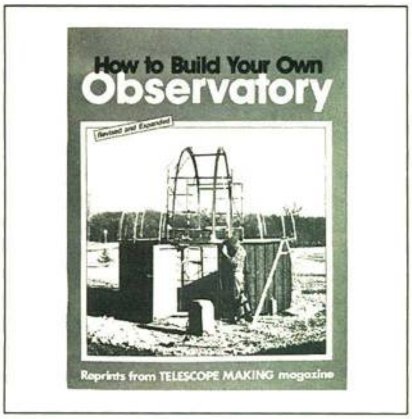
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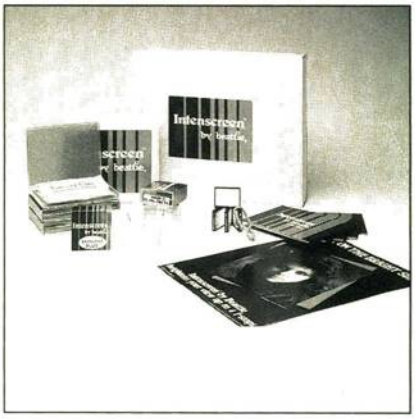

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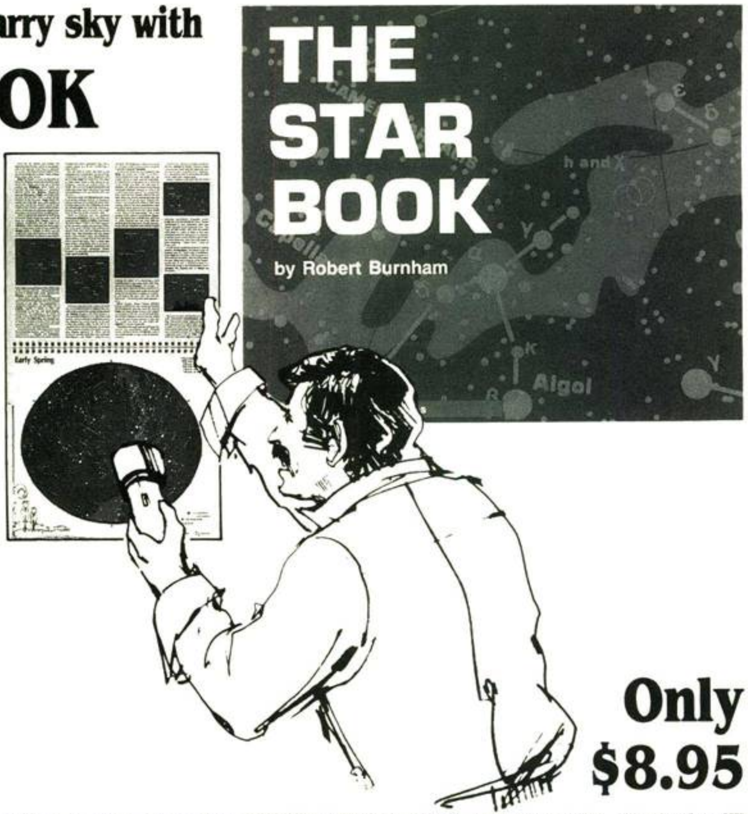

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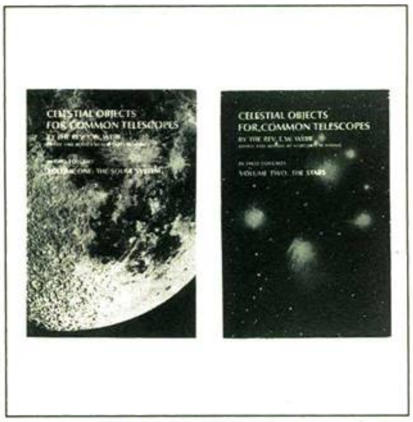
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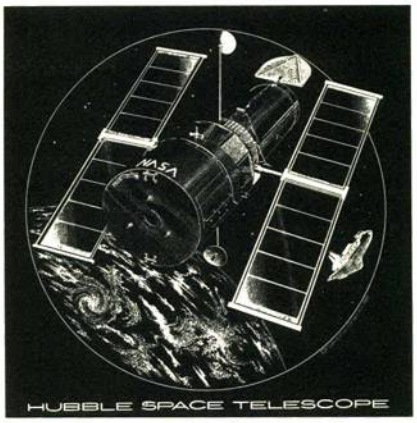

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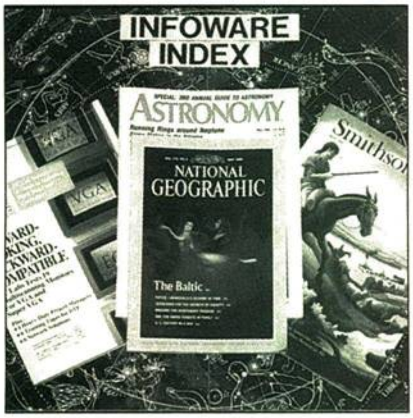

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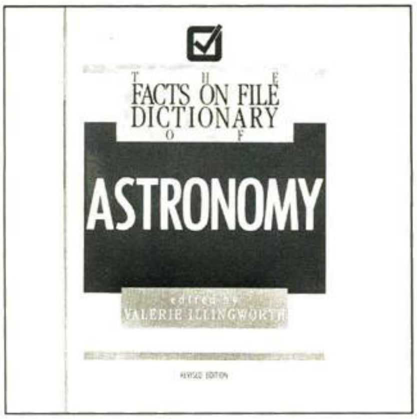

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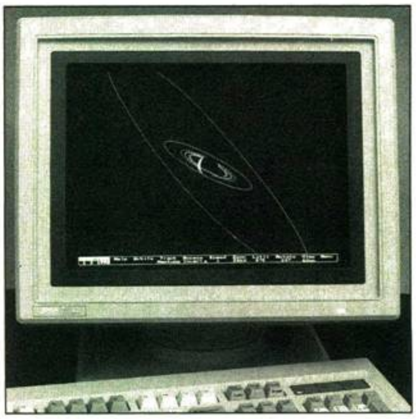

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SPLIT A STAR IN TWO

Here are five close double stars that require extra observing skill to detect their binary nature.

by Alan Goldstein

Double stars have a special place in the realm of deep-sky observing. Unlike deep-sky objects, double stars are immune to light pollution and moonlight. They are available whenever you want to observe as long as the sky is clear. Best of all, slightly hazy evenings — useless for observing nebulae and galaxies — lend themselves perfectly to double star watching. On hazy evenings the atmospheric seeing is generally steady, which allows the starlight to pass through the atmosphere without distortion. The end result is clear, sharp views of close, colorful double stars.

Close double stars, those with components separated by less than five arcseconds, offer a real challenge to backyard observers. Some of these pairs have great magnitude differences between their stars, the secondaries glowing feebly in comparison to the primaries. This difference makes the faint secondary extremely difficult to spot because of glare from the primary star.

The brightest star in the sky, **Sirius** (Alpha [α] Canis Majoris), is a close double that offers an enormous contrast between its components' brightnesses. Sirius A shines brilliantly at magnitude −1.5, a white beacon that seems like a searchlight in any telescope. Sirius B, the companion, lies about 4″ due north of Sirius A and is a magnitude 8.4 star — about 4,000 times fainter than Sirius A. To see the faint secondary, place an occulting bar — a small strip of cardboard — inside the eyepiece at the focal plane. This will block enough light so that if seeing conditions are steady you should spot Sirius B.

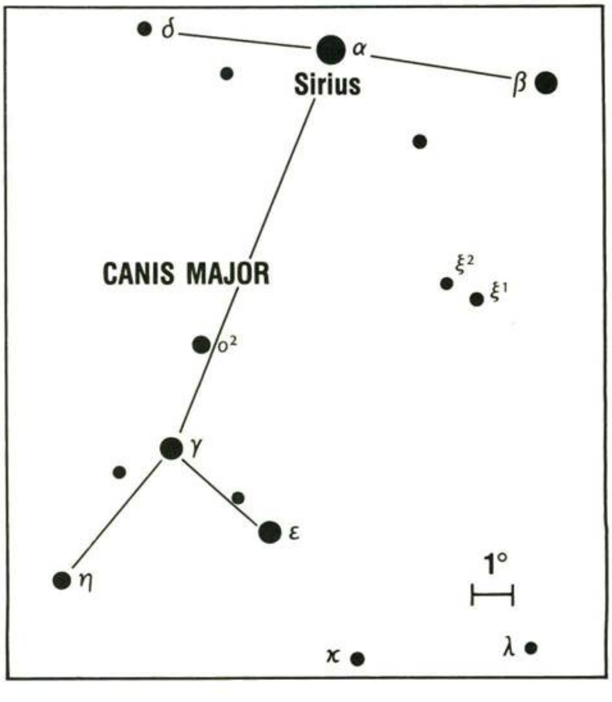
Sirius A is several times more massive and 23 times more luminous than our Sun. Its stark white color results from a surface temperature of 12,000 K and a spectral type of A1. In contrast, Sirius B is a white dwarf, a star with a mass comparable to the Sun's that is compressed into a white-hot sphere only 19,000 miles across.

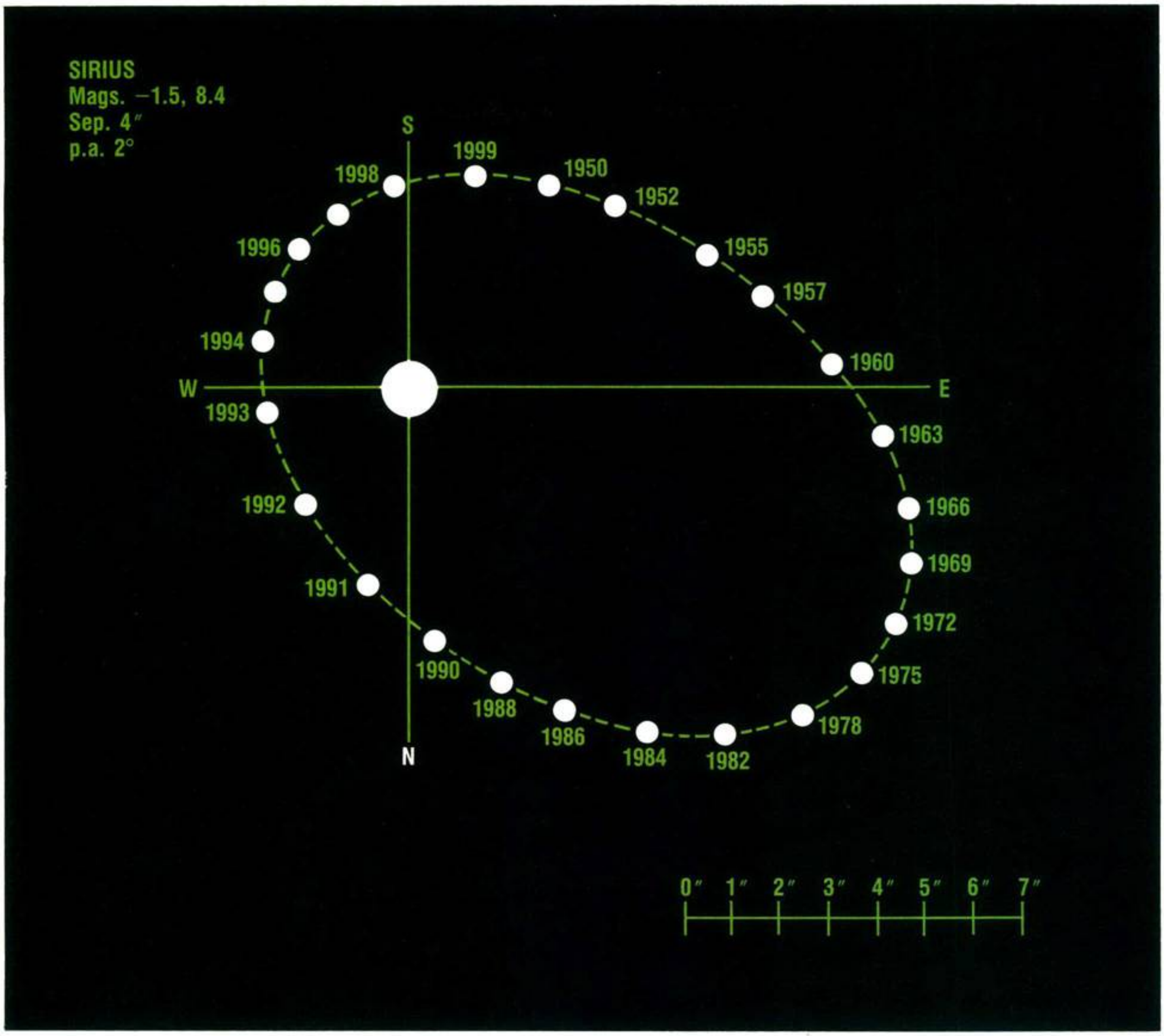
Reasonably close to Sirius in the sky is **Rigel** (Beta [β] Orionis). The seventh brightest star in the sky, Rigel shines at magnitude 0.1. Rigel is a double star with a secondary that glows at magnitude 6.7, considerably brighter than Sirius B. Observing this star is not as difficult as finding Sirius B, although it is still a challenge. Look for Rigel B with a high-power eyepiece some 9″ south of Rigel A. As with Sirius, you may have to use an occulting bar to block light from the primary.

Both components of Rigel are visible without difficulty in a 4-inch refractor. In large telescopes Rigel is one of the finest double stars in the winter sky; both stars show a slight bluish tint. Rigel B itself is a close binary, never exceeding a separation of 0.2″. When observing with large telescopes, some observers have reported Rigel B to be elongated. Can you see anything unusual when looking at Rigel B?

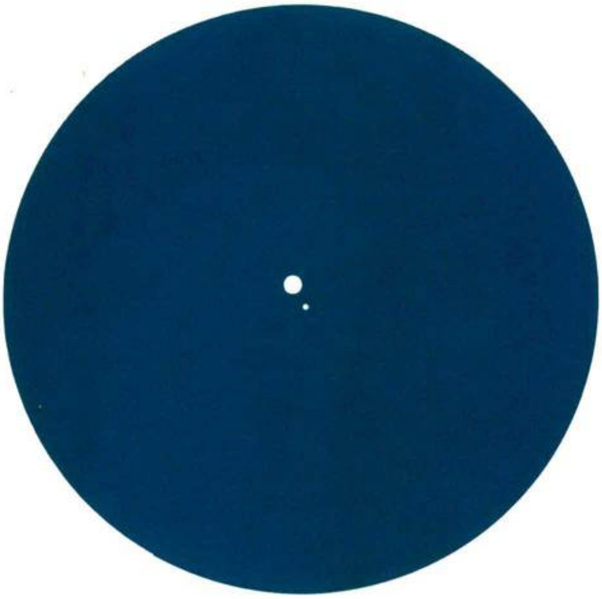
The similarity between Rigel A and B and Sirius A and B is purely visual. Rigel is one of the most luminous stars known in our Galaxy, over 55,000 times brighter than the Sun. In our sky Rigel is 1.5 magnitudes fainter than Sirius, yet Rigel lies 900 light-years away, more than 100 times more distant than Sirius. Rigel B lies more than 200 billion miles from Rigel. At that distance you would have to observe Rigel A and Rigel B for over two hundred years to detect any orbital motion.

Castor (Alpha Geminorum) is another challenging star for double star observers. Castor A and B shine at magnitudes 2.0 and 2.8. The stars are separated by a mere 2″, which makes splitting this pair rather challenging. The system reached periastron in 1969 (1.8″) and will slowly widen to 6.5″ over the next 110 years. The orbital path is inclined 25° from the edge-on position, making the two components much more difficult to observe when their orbital motion carries one star

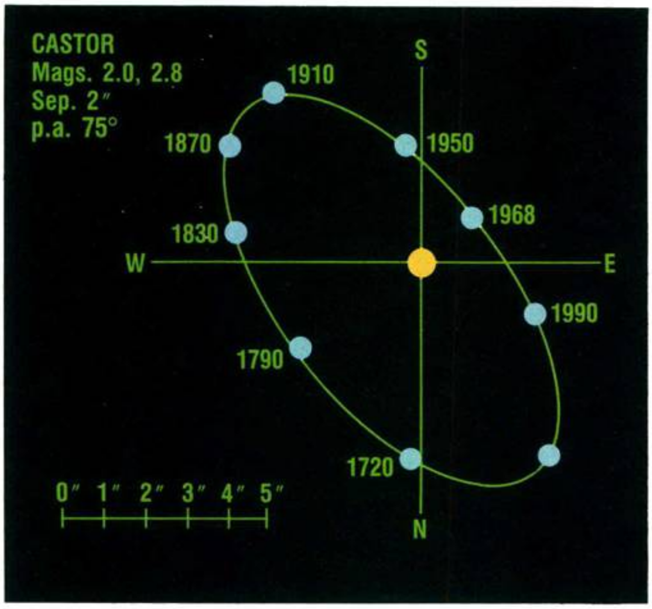


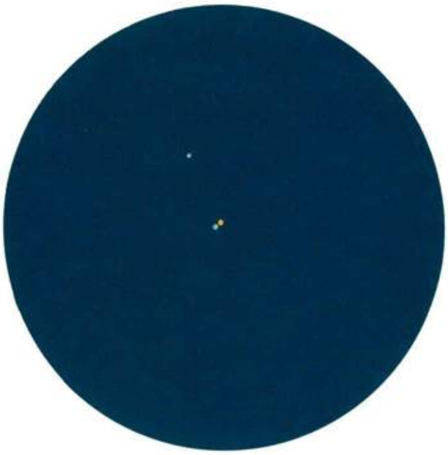

SIRIUS
Mags. −1.5, 8.4
Sep. 4″
p.a. 2°
S
N
W
E
1999
1950
1998
1952
1996
1955
1957
1994
1960
1993
1963
1992
1966
1969
1991
1972
1990
1975
1988
1978
1986
1984
1982
0″ 1″ 2″ 3″ 4″ 5″ 6″ 7″

THE BRIGHTEST STAR IN THE SKY, Sirius is a close double with an 8th-magnitude secondary. Splitting Sirius requires a large telescope and an occulting bar placed in the eyepiece.

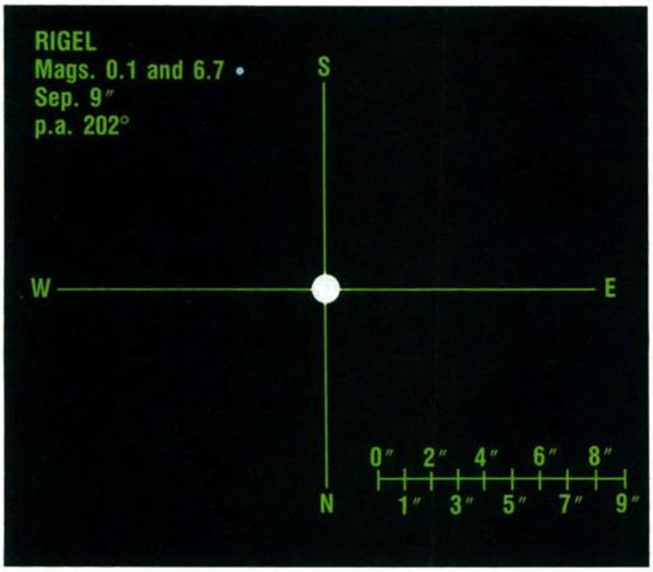


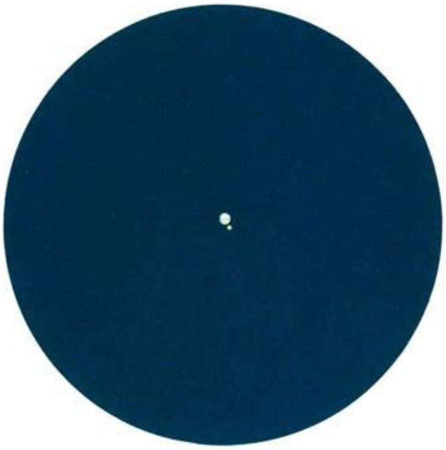
Sirius
8-inch f/10 SCT at 200x
by David J. Eicher


CASTOR
Mags. 2.0, 2.8
Sep. 2″
p.a. 75°
S
N
W
E
1910
1870
1950
1968
1830
1990
1790
1720
0″ 1″ 2″ 3″ 4″ 5″

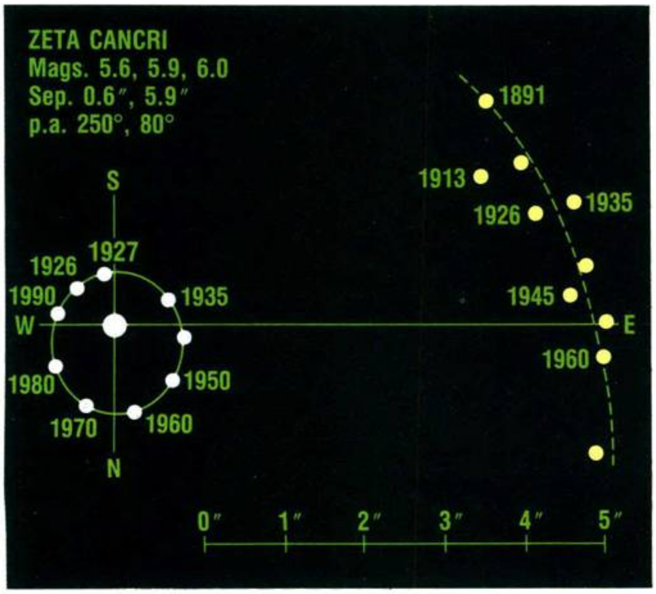


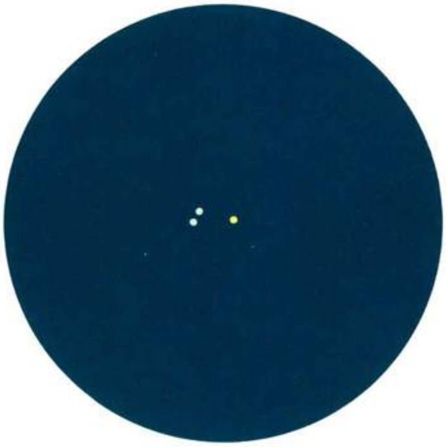
Castor
3-inch f/10 Reflector at 120x
by Glenn F. Chaple, Jr.


RIGEL
Mags. 0.1 and 6.7 •
Sep. 9″
p.a. 202°
S
N
W
E
0″ 2″ 4″ 6″ 8″
1″ 3″ 5″ 7″ 9″

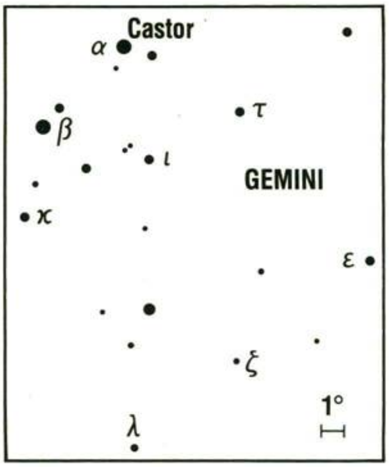


Rigel
3-inch f/10 Reflector at 120x
by Glenn F. Chaple, Jr.


ZETA CANCRI
Mags. 5.6, 5.9, 6.0
Sep. 0.6″, 5.9″
p.a. 250°, 80°
S
N
W
E
1927
1926
1990
1935
1980
1950
1970
1960
1891
1913
1926
1935
1945
1960
0″ 1″ 2″ 3″ 4″ 5″



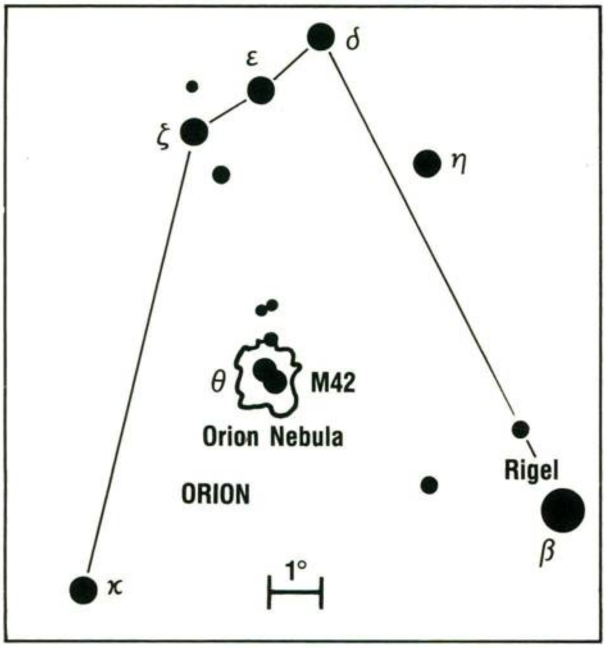
Zeta Cancri
6-inch f/8 Reflector at 200x
by James Mullaney



Close, Challenging Doubles

Object	R.A. (2000.0) Dec.		Mag.	Sep.	P.A.
Rigel	5h14.5m	−8°12′	0.1, 6.7	9″	202°
Sirius	6h45.1m	−16°43′	−1.5, 8.4	4″	2°
Castor	7h34.6m	+31°53	2.0, 2.8	2″	75°
Zeta Cancri	8h12.2m	+17°39′	5.6, 5.9, 6.0	0.6″, 5.9″	250°, 80°

Object: Star name. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitudes of component stars. **Sep.:** Separation of components in arcseconds. **P.A.:** Position angle in degrees.



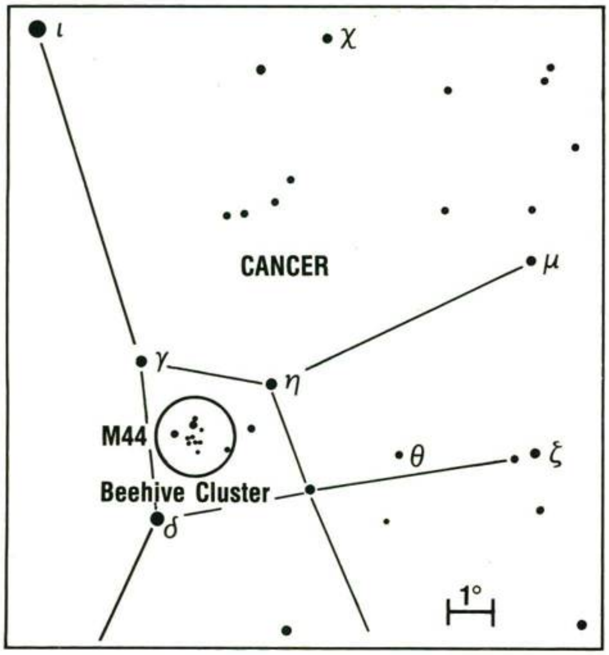
nearly in front of the other. Lying 72.5″ distant in position angle 164° is a third member of the Castor system. At magnitude 9.1, this red dwarf lies more than 100 billion miles from the other stars and has an orbital period exceeding 10,000 years.

A triple star system is unusual, but Castor does not stop there. Each member of the Castor system is also a binary, too close to be resolved with optical telescopes. Castor A² has an eccentric orbit around A¹ and completes one revolution every nine days. Castor B's components revolve in a three-day circular orbit. Castor C, also known as YY Geminorum, is an eclipsing binary. The stars eclipse each other every 9.8 hours, causing a measurable drop in the system's brightness.

Our last challenging star is **Zeta Cancri**, located about 5° west and slightly south of the Beehive Cluster. To the unaided eye, Zeta Cancri is simply an inconspicuous 5th-magnitude star. However, a 10-inch scope reveals that Zeta Cancri is a triple system. All three stars have a yellowish cast due to similar spectral types of F8, G0, and G2. The A and B components shine at magnitudes 5.6 and 5.9 with a separation of just 0.6″. At the computed distance of 71 light-years, the stars have a real separation of 1.8 billion miles — about the distance between the Sun and Uranus.

Zeta Cancri's third component (Zeta C) is a 6th-magnitude star lying 5.9″ distant in position angle 80°. Its quick orbital motion around the A-B pair has carried it through a position angle change of more than 70° over the past 150 years. Zeta C is also no loner: it is an astrometric binary, a star detectable as a double only by precise measurements of its motion in the sky. Zeta C's companion lies at a distance of about 500 million miles and is too faint to see visually, suggesting that it may be a white dwarf star or another object with an extremely low luminosity.

These four challenges merely represent the tip of the iceberg in double star observing. Thousands of challenging doubles — close pairs with striking differences in brightnesses and colors — are visible in backyard telescopes. Spend some time with these objects and you'll find that splitting the stars is a lot of fun. ☐



Alan Goldstein is a curator of science at the Museum of Science and History in Louisville, Kentucky. In 1976 he founded the National Deep Sky Observers Society, an international group of deep-sky observers.

Finding the Best Observing Site

The quality of an observing site depends on observing conditions and the convenience of the site.

by Tim Hunter

How often have you said to yourself: "It's almost not worth taking my telescope out in the backyard anymore, what with all the light pollution around here, but I don't like driving 50 miles to get to my dark-sky observing site either"? Most observers face a similar dilemma. Unless you live in an area blessed with dark skies, good weather, and a lot of available land, eventually you'll want to decide whether a distant site with great observing conditions is worth the hassle compared to a relatively poor site close by.

Although amateur astronomers can't evaluate observing sites the way professional astronomers do — by monitoring the seeing, transparency, and weather conditions over a long period of time — they can benefit from making a similar, albeit less-sophisticated, analysis. What you need to do is think critically about the factors that make for a good observing site.

One way to sharpen your thinking on the subject is to use an observing site index to evaluate the merits and drawbacks of each potential site. In general, an observing site index can be defined as the observing conditions at the site divided by the site's accessibility.

Although no index can be all things to all people, I've found one that has proven helpful to me. In mathematical terms this index can be written:

Observing Site Index = $T \times W \times A \times S \times V/(E \times F \times D)$.

In this equation, T stands for transparency, the limiting visual magnitude overhead on clear, moonless nights; W for weather, the fraction of nights suitable for observing (consider cloud cover, temperature, wind, and moisture); A for altitude, the number of feet above sea level, divided by 1,000; S for average seeing, on a scale of 1 (terrible) to 10 (terrific); V for view, the fraction of the total sky free of overt urban sky glow and horizon obstructions; E for expense, the cost of the site in dollars, divided by 1,000; F for fuel, the cost in dollars of fuel and depreciation, divided by 10; and D distance, the time it takes to get to the site and set up in hours.

The higher the index, the better the observing site. You can give any of these factors more or less weight depending on your situation. For example, if you live in an area where there is little topographic relief, such as the Midwest, the altitude of competing sites won't vary enough to make much difference. In such instances, you can eliminate that factor by setting A equal to 1. Likewise, if you own or have free access to the land where a potential site is located, the expense (E) can be set to 1.

If you want to compare your backyard with other observing sites, you have to alter the fuel factor. I generally set F equal to 1 for my backyard because that figure is significantly lower than the value for any remote site I would choose. Finally, don't forget to include your set-up time in the distance parameter. It is sometimes easier to drive several miles to a permanent facility where you can start observing quickly than to drag bulky equipment into your own backyard.

To see how the observing site index helps in evaluating different sites, let's compare the two sites I use most frequently: my backyard in Tucson, Arizona, and the Grasslands Observatory, a remote site where my friend and I recently built an observatory. The sky conditions at the Grasslands Observatory are nearly ideal, but the site is an hour and fifteen minute drive from my home. In this case, T is 7.5 (the limiting magnitude overhead on the finest nights); W is 0.8 (80 percent of the time there are reasonable weather conditions); A is 5.0 (the altitude is 5,000 feet); S is 6 (average seeing is 6 on a scale of 1 to 10); V is 0.9 (90 percent of the sky is free of visible urban sky glow); E is 1 (I own the land); F is 2.0 (it costs \$20 to drive the 100-mile round trip, using 20 cents a mile as a standard value for fuel and depreciation); and D is 1.25 (it takes an hour and fifteen minutes to get there). Thus the observing site index is

$$7.5 \times 0.8 \times 5.0 \times 6 \times 0.9/(1 \times 2.0 \times 1.25) = 64.8.$$

The observing conditions at my house in Tucson are poor because of generally bad seeing, considerable light pollution, and a lower altitude. (The Tucson site has the following values: T is 5.0; W is 0.8; A is 2.0; S is 3; and V is 0.4.) Nevertheless, the accessibility is much greater because it takes only ten minutes to set up my telescope. Thus, the observing site index at my home is

$$5.0 \times 0.8 \times 2.0 \times 3 \times 0.4/(1 \times 1.0 \times 0.2) = 48.0.$$

Interestingly, my backyard gets only a slightly lower rating than my dark-sky site. This reflects the fact that I'm much more likely to observe from home than to drive more than an hour each way to the Grasslands site.

The purpose of the observing site index is to help you to consider all the factors involved in picking a site. Just remember to be consistent and evaluate every site by the same criteria. If calculating an index makes you weigh observing conditions versus site accessibility seriously, then it will have served you well. ☐

Tim Hunter is an amateur astronomer who lives in Tucson, Arizona.

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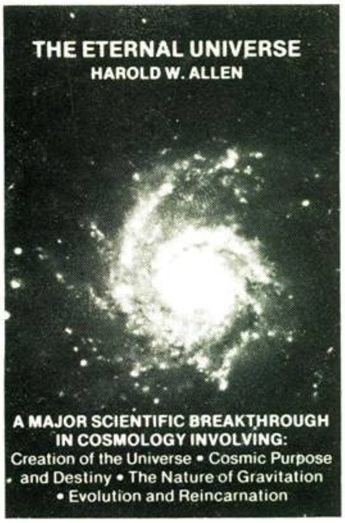
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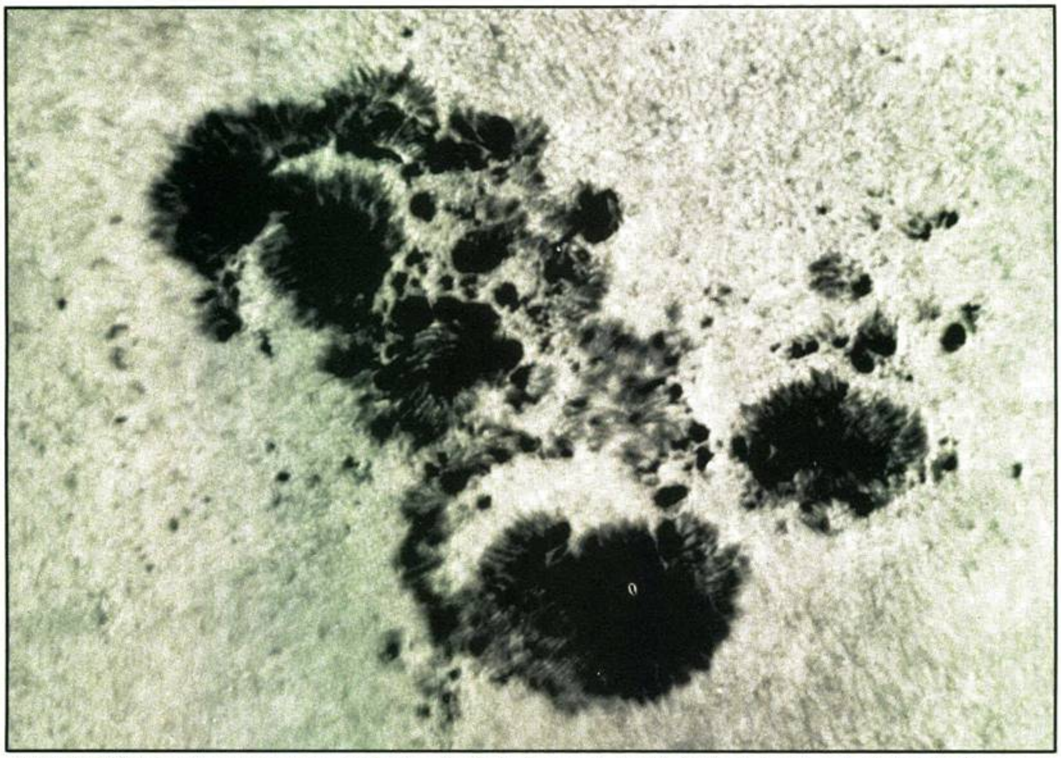

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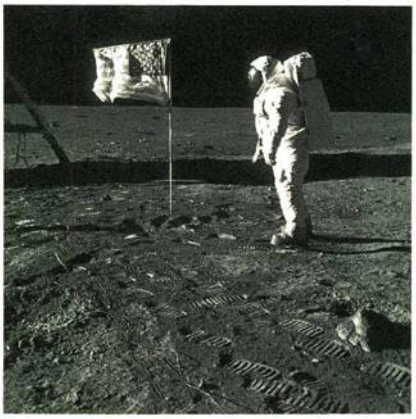

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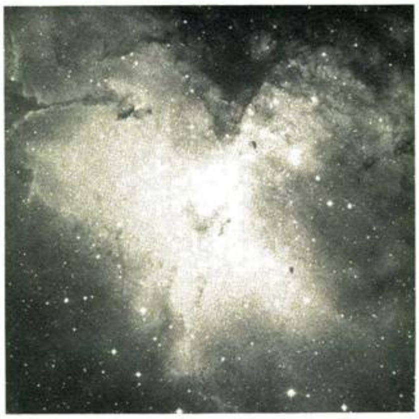

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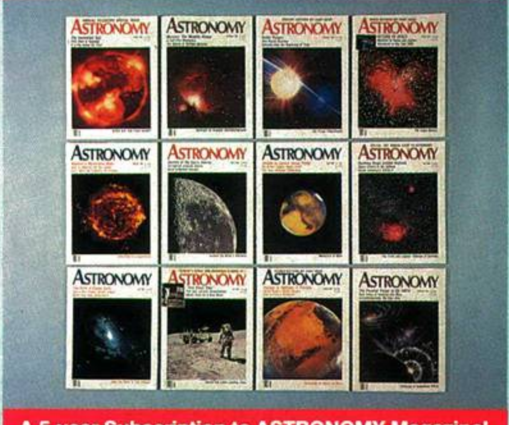

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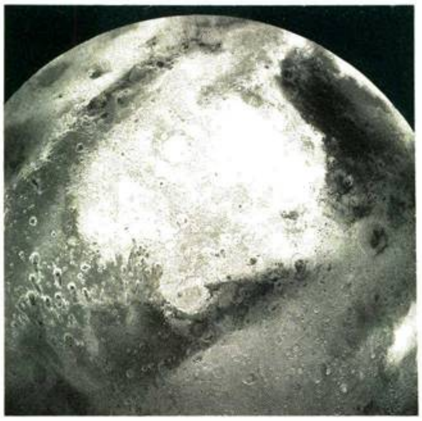

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AN 'EYEBALL IN THE SKY'

In one of the finest lunar eclipses of recent times, Earth's shadow darkened the Moon for over ninety minutes on the evening of August 16. (See "The Summer Eclipse of the Moon," page 78.) The eclipse was fully visible in the eastern and central parts of the United States, South America, western Europe, and western Africa. Observers in the western United States saw an already-eclipsed Moon rise and could follow the Moon's progress as it left Earth's shadow.

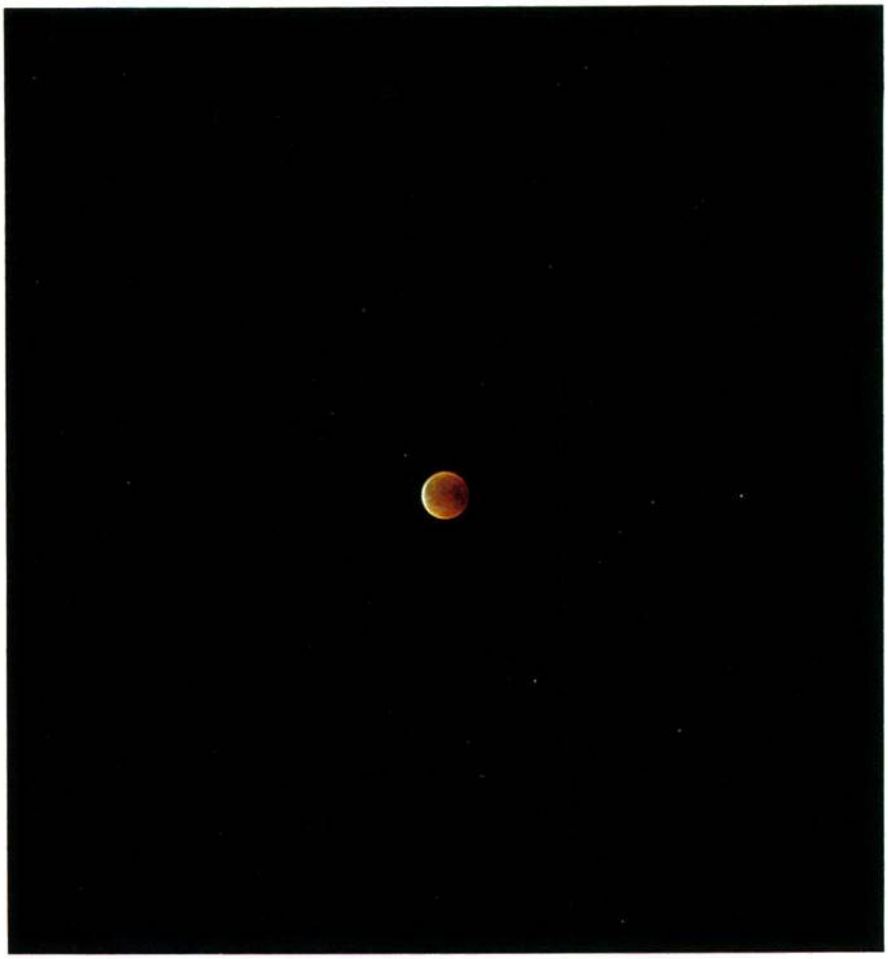
By all accounts August's eclipse was a reasonably dark one. "When totality ended and sunlight began to creep across the Moon's face, the Moon looked like a giant eyeball in the sky," said Steve Lake, a member of the Milwaukee Astronomical Society in Milwaukee, Wisconsin. "It was positively eerie." The eyeball effect resulted from the immense contrast between the sunlit portions of the Moon and the dark, still-eclipsed regions. During totality the Moon faded to a rusty brown and practically dropped out of sight for naked-eye viewers.

Midwestern observers got the best draw on the weather: many East Coast eclipse watchers were clouded out for at least part of the event. From Uniontown, Ohio, Ray and Jerry Coia observed the eclipse in near-infrared, using a 6-inch reflector and a voltmeter to measure the heat bouncing off of the Moon's surface. They found that at 9:16 p.m. EDT the voltmeter read 5.0 volts, but measurements began to drop off quickly and by 10:18 p.m., after totality began, they got a reading of 0.02 volts. The Moon's infrared emission began to rise again at 11:55 p.m. and was up to the normal Full Moon level of 7.6 volts by 12:51 a.m.

Observing from Halifax, Nova Scotia, Michael Boschat reported that "weather prospects were not promising, with fog and scattered clouds present on the evening of the eclipse." However, Nova Scotia was in luck. "The fog dissipated," said Boschat. "I set up my 3-inch refractor and began to watch. By mid-eclipse I noticed a slight red tinge. Overall, the eclipse was extremely dark."

COMET BRORSEN-METCALF BRIGHTENS

During August 1989 periodic Comet Brorsen-Metcalf brightened from 8th-magnitude to 6th magnitude with a 1°-long tail. "This year's great little comet is progressing splendidly," said Martin Hale of Simi Valley, California. "I



A SEA OF STARS surrounds the eclipsed Moon just after the end of totality. Photo by Ronald Royer using a 4-inch f/5 astrograph, Ektachrome 64 film, and a 2-minute exposure.

MOON DRIFT DURING THE ECLIPSE shows how far the Moon moves relative to the star background in ninety seconds. Ronald Royer used an 18-inch f/7 reflector, Ektachrome 64 film, and guided on the star 44 Capricorni.

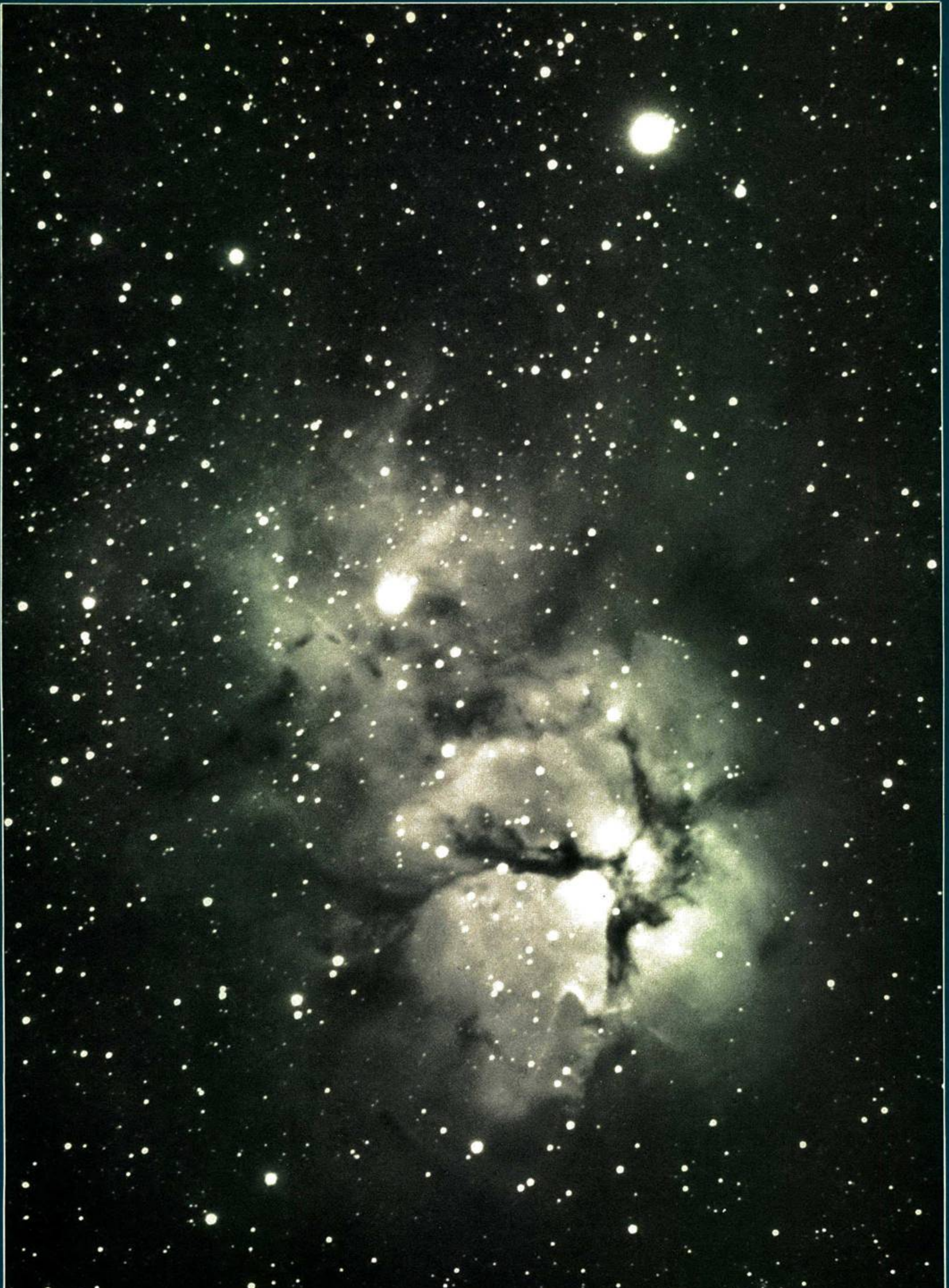
A RUSTY BROWN MOON greeted observers who watched August's lunar eclipse. John Hicks' portrait of the event shows the Moon shortly after the end of totality as the Moon emerged from Earth's shadow.

THE FAINT LIGHT OF DEEP-SKY OBJECTS

The Trifid Nebula, a large, faint gas cloud, is one of the most spectacular deep-sky objects in the summer Milky Way. The Trifid derives its name from the three veins of dark material superposed in its surface. Californian Chuck Vaughn's photo of the Trifid Nebula (opposite page) nets this month's $100 "Best Astrophoto" award. Vaughn used a 14-inch SCT at f/7, hypersensitized Tech Pan film, and a 60-minute exposure. A wide-field view shows both the Lagoon and Trifid nebulae, as in Michael Stecker's photo (bottom left). Stecker used an 8-inch f/4 hyperbolic reflector, hypered Konica 3200 film, and a 40-minute exposure.

Jack Newton stalked fainter deep-sky objects when he photographed the southern half of the constellation Orion (left center). Newton's photo shows outlying nebulosity around the Orion and Horsehead nebulae, as well as Barnard's Loop. Kim Zussman captured the faint group of galaxies called Stephen's Quintet (top left). Zussman used an 11-inch f/10 SCT, hypered Tech Pan film, and a 240-minute exposure.

Solar system photography yields a record of the ever-changing sky. Bill Sterne captured sunrise over Tulsa, Oklahoma, in a dramatic multiple-exposure shot (below). Stern photographed the Sun at f/16 at 4-minute intervals on Fujichrome 160 film.



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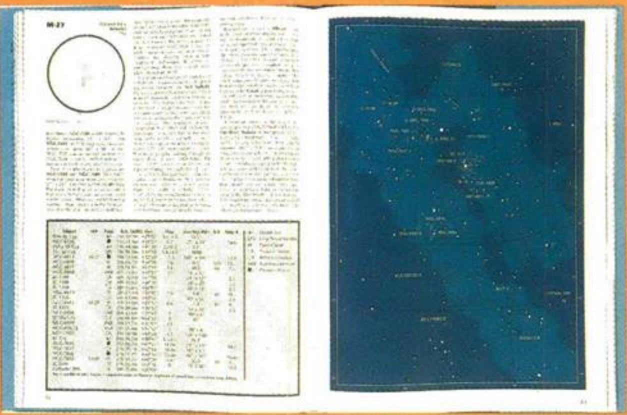

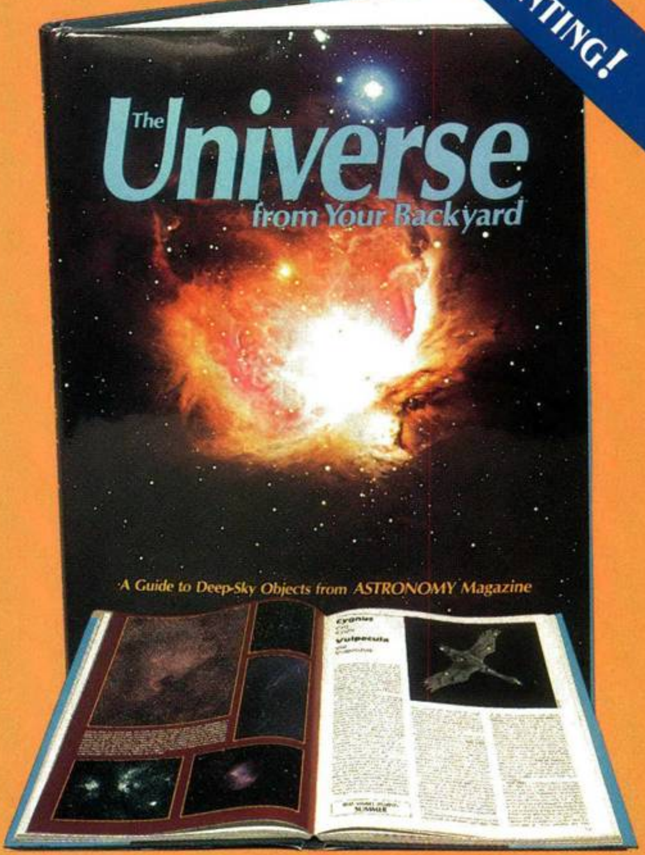
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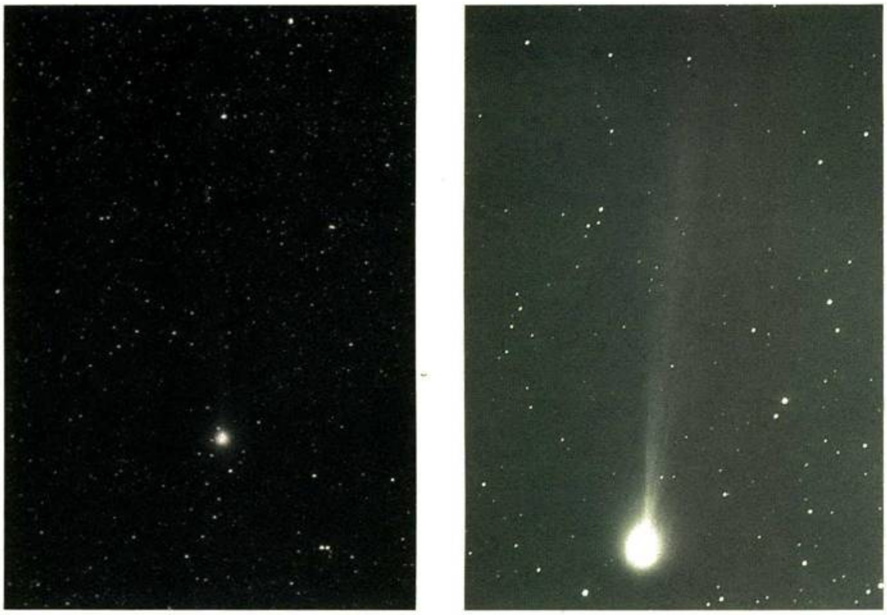
observed the comet on August 14, when it appeared to shine at magnitude 6.8 and had a slender tail streaming westward. The comet and tail were visible in 10x50 binoculars and my 4-inch f/10 guidescope." At press time, Brorsen-Metcalf had a magnitude of 6, making it visible with the naked eye from a dark site.

PERSEIDS PROVIDE SKY SHOW

Bright meteors arced overhead on the night of August 12, 1989, during the maximum of the annual Perseid meteor shower. Although the Moon was just four days short of Full, hundreds of skywatchers lay back and looked up, hoping to see as many as fifty meteors per hour.

The excitement was contagious. "I just had to tell you about my Perseid observations," said Jill Tolk of Twin Falls, Idaho. "I observed the shower from 11:30 p.m. on August 11 to 5:30 a.m. MDT on the morning of the 12th and counted seventy-five meteors between 2:30 and 3:30 a.m."

From Callahan, Florida, Karl and Wanda Simmons and their family and friends watched for meteors during the



COMET BRORSEN-METCALF increased dramatically in size and brightness during August 1989. Martin Hale's photograph (left) shows the comet on August 4. Hale used an 8-inch f/1.5 Schmidt camera, hypered Tech Pan film, and a 5-minute exposure. Chris Schur's photo (right) shows the comet on August 29. Schur used a 14-inch f/5 reflector, hypered Tech Pan film, and a 15-minute exposure.

Mingle with the stars...
Photo by Tony Hallis

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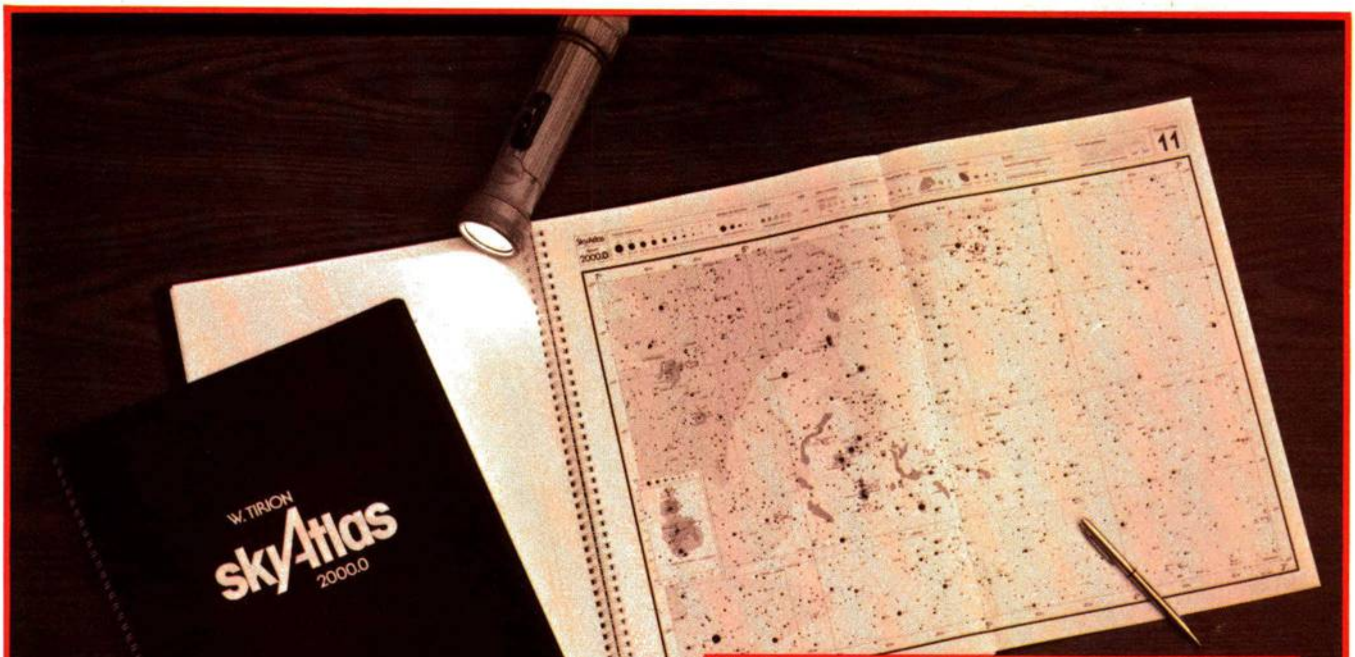
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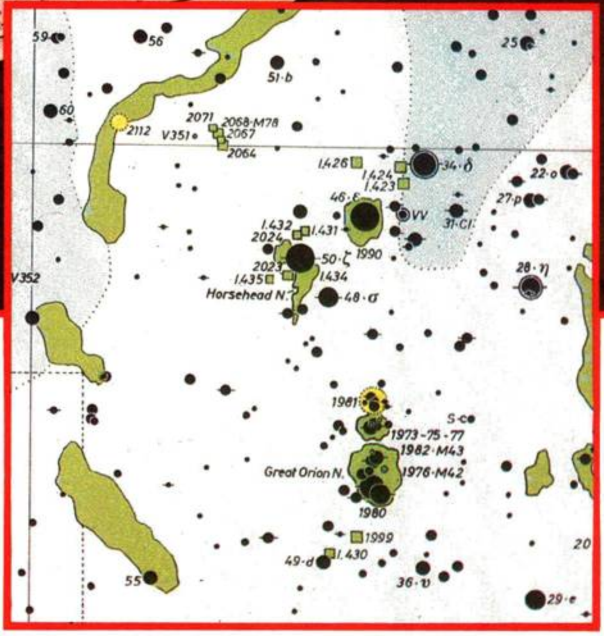
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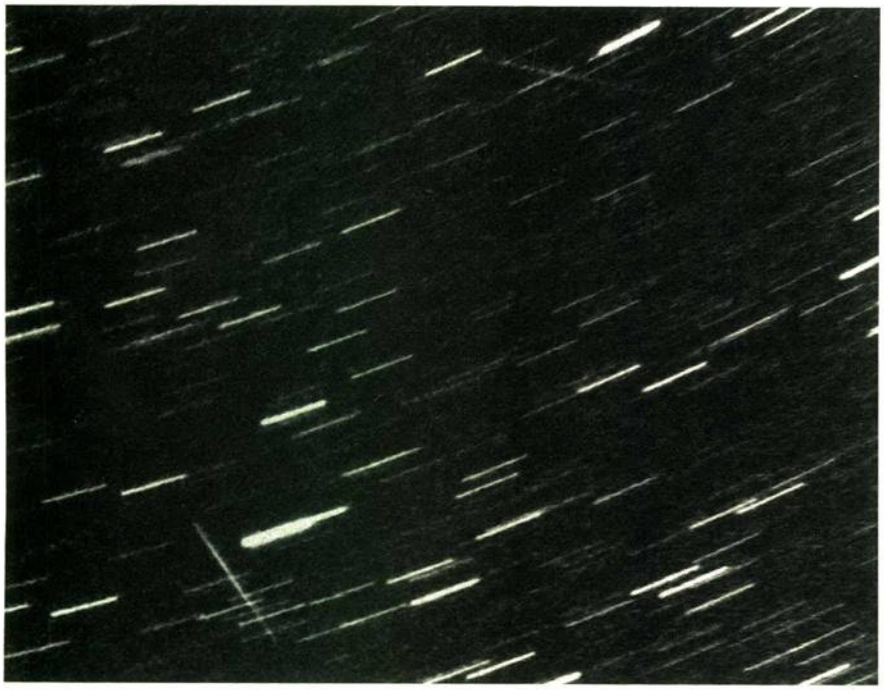

PERSEID METEORS were visible in abundance last August 12. John Paul Thielen recorded two Perseids in this photo made with a 28mm f/2.8 lens, TMAX 400 film, and a 4-minute exposure.

first two weeks of August despite periodic clouds and poor weather conditions. Observing on the morning of August 12, Karl Simmons reported forty-four meteors between 5:05 and 5:50 a.m. EDT. Of these, Simmons believes that thirty-seven were Perseids, six were sporadics, and one was a South Delta Aquarid. Simmons' seven-year-old son Stephen also reported thirty-seven meteors during the same period, thirty-four of which were Perseids.

"This year's Perseid shower seemed better than last year's," said George W. Gliba of Greenbelt, Maryland. "On the night of maximum, I observed two hundred meteors during the three-hour period from 2:00 a.m. to 5:00 a.m. EDT. Of these, 156 were Perseids. The most spectacular of these included six −1-magnitude meteors, four −2-magnitude meteors, and two very nice −3-magnitude meteors. One of these left a train that remained visible for more than thirty seconds. The colors ranged from white to blue-white to yellow, and the average magnitude was 2.5. About 37 percent of the meteors left a train. I was delighted." — *David J. Eicher.* ☐

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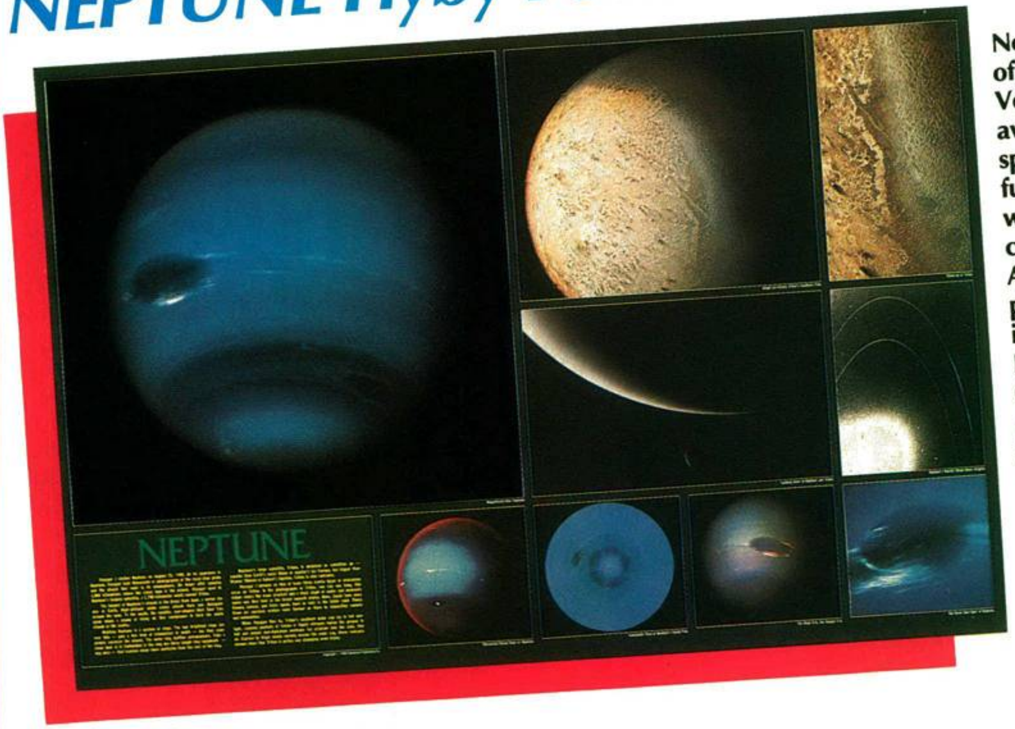

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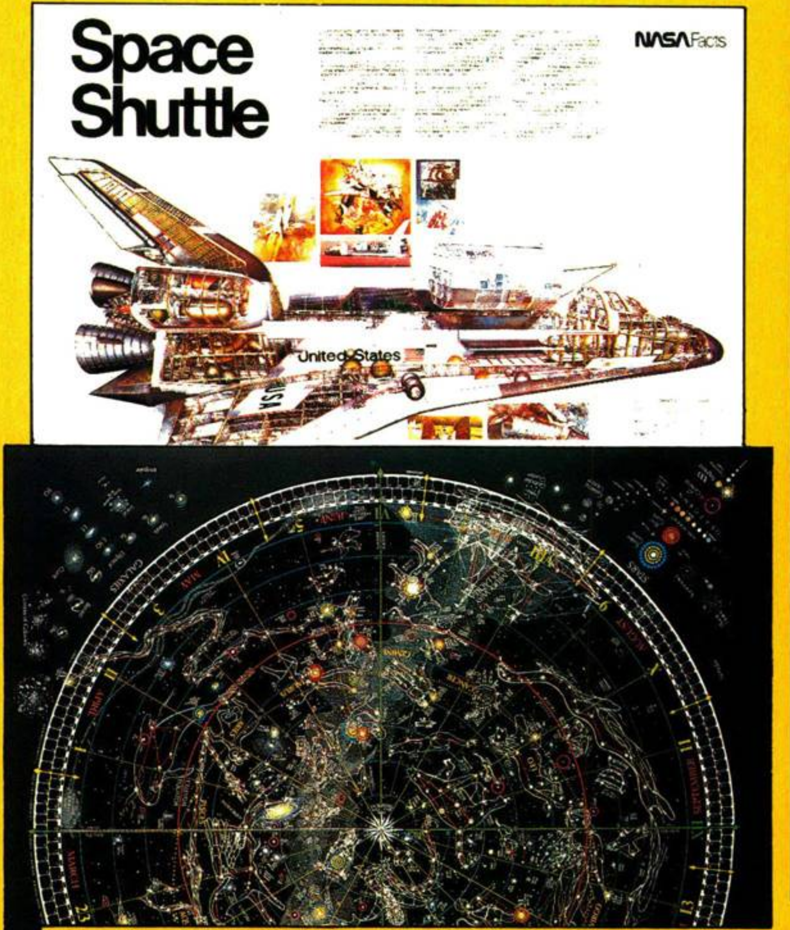

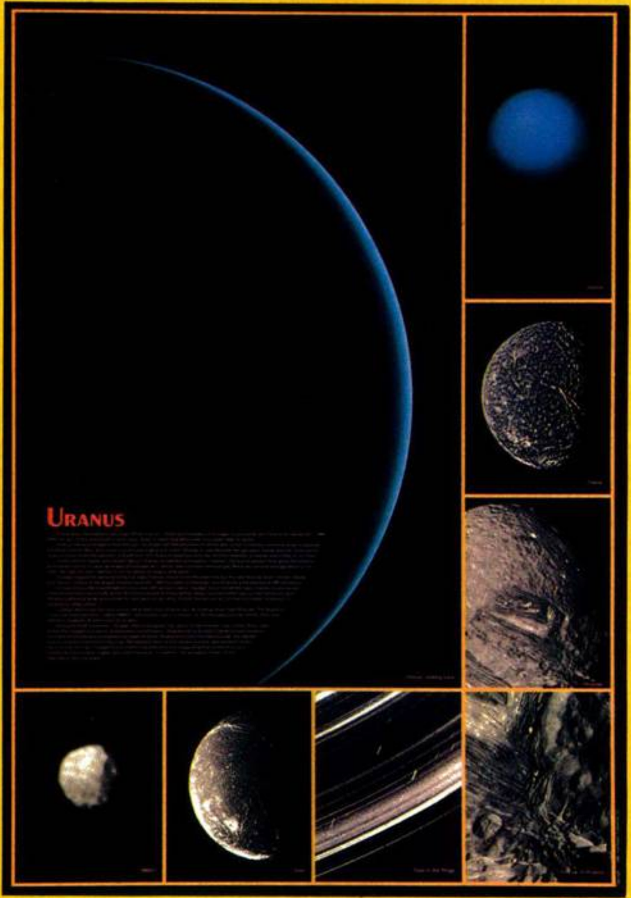

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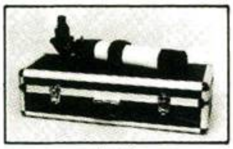

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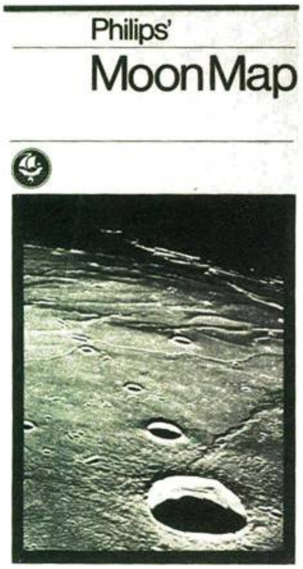

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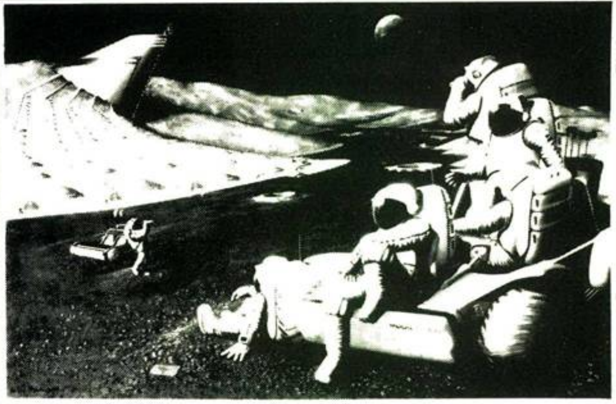

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ASTRONOMY's reply typically runs like this: "Thanks for your inquiry. We get many letters and phone calls about this; you're not the first, nor will you be the last! The names given to all astronomical bodies are made official only when the International Astronomical Union chooses them. This is the only source for scientifically recognized celestial names, and needless to say, the IAU's services are not for sale. As long as you recognize that you're handing over money on a whim, there's no fraud involved — but no astronomically recognized fame or glory either."

To find out more about the star-naming business, I spoke with Phyllis Mosele, president of the International Star Registry, which is located in Northfield, Illinois. A cheerful, friendly woman, she informed me that ISR is ten years old this year; she has been president for the past eight years. "I love it," she said enthusiastically. "What we do is neat, fun, and thoughtful."

Not everyone would agree. Like ASTRONOMY, the American Astronomical Society (AAS) gets frequent requests for information about the star-naming business because the AAS is the main professional organization to which most U.S. astronomers belong. Such calls come in about once a week, and Carol Hartley, publications coordinator for the society, handles most of them. She said her practice is "to explain to people why we don't think it's a good idea. The AAS basically views star naming as a scam."

Mosele maintains that ISR has never laid claim to any scientific legitimacy or recognition for its services. "We've never claimed any scientific status; that's not our purpose. Astronomers don't have to like it. Professional astronomy is completely unrelated to what we do," she said.

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Kate
$
Steve
Doug
Al

This progression may serve as a hint of the volume of ISR's business. According to Phyllis Mosele, the company's gross annual revenues total $1.5 million. For another measure of ISR's size, consider this: during the winter holiday season (the company's busiest time of year) as many as 120 people are employed filling orders that come in over twenty-six telephone lines. A typical holiday season results in about 20,000 new orders.

Most of ISR's income represents the sale of star names, but some comes from a related source: the sale of books that list the names assigned by ISR. A new edition of the book, entitled *Your Place in the Cosmos*, is published every four or five years. The first edition in 1984 included about 150,000 names; the second, in 1988, listed that many again, with no overlap between the two volumes.

When the book is published, ISR copyrights it by sending a copy to the Library of Congress and paying a $10 fee. That act enables the company to claim that its star names are "registered." Initially, ISR tried to copyright its list of names by simply sending a microfilm list to the Library of Congress. The library refused to accept the film due to uncertainty over its authorship. Also, the company's use of the Library of Congress' name in its promotional materials upset the library to such an extent that in December 1984 it issued a press release explicitly disclaiming any connection with the International Star Registry.

The Library of Congress press release read in part: "The Library has repeatedly emphasized that it has no connection whatsoever with any star registry. . . . It should be pointed out that a copyright registration does not guarantee the authenticity of the information contained in those works. . . . As a compilation, the [ISR's] list is eligible for copyright, much like any phone book. . . . It is important to note, however, that such copyright protection extends only to the authorship of the compilation and not to the association of any proper name with any star or planetary feature. Theoretically, the same star could be 'sold' to two different individuals by two different star registration systems without any copyright violation."

Some of ISR's promotional literature claims that the star names are registered "in the vaults in Geneva, Switzerland." What this impressive-sounding claim means, according to Phyllis Mosele, is that ISR makes a microfilm of each edition of its book and deposits the film in a Swiss safe-deposit box.

The books also represent a source of income to ISR, and the company markets them directly to the customers on its mailing list. They have found that people who are impressed by the elaborate certificate are likely to be even more impressed by seeing their own name or their loved ones' names in an actual book.

Mosele says the third edition of ISR's book will be published in 1991. "We expect it to have at least as many names as either of the previous volumes" — that is, 150,000 or so. Some of those listed are the folks next door, some are celebrities, and some are corporations, who buy star names as a morale booster for their "star" salespeople.

Recently, more and more of ISR's customers have bought star names as a memorial to someone who has died.

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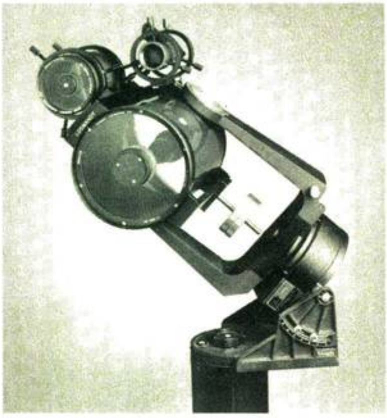

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Phyllis Mosele says she was surprised by this development. "I'd always thought of it as something happy and fun," she admitted. Now ISR has an arrangement with a funeral casket company, Casket Shells, Inc., of Pennsylvania, to market the "memorial star" concept in the funeral industry.

ISR has other relationships with firms that market its service. These firms take orders that ISR fills, and the firms receive a share of the profit on each order. Probably the best known of these is a company called Jumpin' Jupiter in San Diego, California, which books most of ISR's West Coast orders. In addition, ISR has foreign representatives in London, Copenhagen, Brussels, and Tokyo. The Tokyo office, unlike the other firms, prints its own certificates, because they have to be in Japanese.

The accusation is frequently made that star-naming companies could, and perhaps do, simply "sell" the same star over and over again to different people. Nonsense, said Phyllis Mosele, "we don't have to cheat, there are millions of stars."

Stars are selected this way: using a custom-designed program, ISR's computer reads photographic plates from the *True Visual Magnitude Photographic Star Atlas* by Papadopoulos and Scovil and picks out 10th-magnitude stars. These are then assigned, one by one, to customers. The charts provided to help customers locate "their" star consist of a map of the appropriate constellation, on which the computer program marks the position of the star it has selected. The star's location is then circled by hand, and telescope coordinates are provided.

So is it a scam, this business of naming stars after people? If charging a lot of money for something that has absolutely no intrinsic worth constitutes a scam, then the answer is yes. But ISR's gimmick isn't the only foolish way for people to spend money on worthless gifts — remember the Pet Rock craze from several years ago? Many people bought those, just as today they buy ISR's certificates. Your decision depends on whether you consider the experience worth the cost.

But if you want to buy a gift for someone who loves astronomy, then you might want to peruse the gift catalogs published by the Astronomical Society of the Pacific and other institutions. If you want to honor the memory of someone you love who has died, then you'll surely accomplish more by making a donation to their favorite charity than you will by buying a listing for them in a book that ISR will then try to sell to you.
— *Lys Ann Shore* ☐

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THE REALITY OF INVISIBLE MATTER

Invisible Matter and the Fate of the Universe by Barry Parker (Plenum Publishing, 1989), ISBN 0-306-43294-3, hardcover, 330 pages, $23.50.

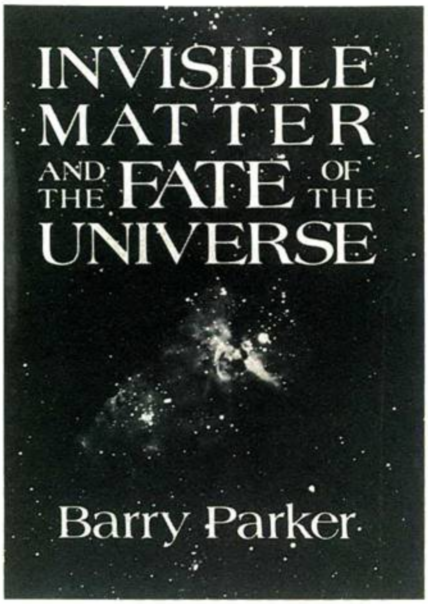
Barry Parker, author of such acclaimed books as *Search for a Supertheory* and *Einstein's Dream: The Search for a Unified Theory of the Universe*, obviously likes to write about ultimate questions and how scientists go about searching for answers to ultimate questions. With *Invisible Matter* Parker continues the cosmological chronicle that he began in his previous book, *Creation: The Story of the Origin and Evolution of the Universe*. In his new book, Parker considers nothing less than the fate of the universe: How will it end? Astronomers believe the answer to this question depends on the answer to yet another question: How much "dark matter" exists in the universe?

Astronomers realized that something was not quite right with the universe over half a century ago. In 1932, Dutch astronomer Jan Oort measured the mass in a given volume of our Galaxy by determining the velocities of stars as they passed through the galactic plane. This was a rather complex procedure that involved measuring the velocities of the stars as a function of their distance above and below the plane, thereby ascertaining the gravitational force acting on them. To his surprise, Oort found that the stellar velocities and stellar masses did not net out: there appeared to be considerably more mass in our region of the Galaxy than the sum of the masses of the stars indicated.

Similar mass deficits were found in 1933 by Fritz Zwicky at Mount Wilson Observatory when he tried to determine the mass of the Coma Cluster. With this galaxy cluster, however, there appeared to be an even larger mass discrepancy, in fact some 200 times larger than that in our Galaxy. The Coma Cluster appeared to weigh more than the sum of the masses of the individual galaxies.

Modern observations have forced astronomers to realize that when they look at sheets of galaxies stretched across great swaths of sky, they are looking at only 10 percent or less of the total mass in the universe. The other 90 percent is contained in immense dark-matter haloes surrounding the galaxies, invisible to the eye. Astronomers don't know what the dark matter is; moreover they don't know why it is invisible. As Parker spells out, these questions must be answered if we are to learn how our universe came to be and what is to become of it.

The first three chapters lay the historical groundwork leading up to the missing-mass controversy: the discovery of galaxies, the expanding universe, establishing a distance scale, mapping the motions of galaxies — all of which depend keenly on the content and mass of the matter that is out there. Parker's use of quotes from the scientists who made discoveries relevant to dark matter keep the historical material from being a reflexive presentation of previous events and facts.



Chapter four addresses modern dark-matter research on the scale of galaxies. Parker tracks important earlier work by individuals such as Jeremiah Ostriker, James Pebbles, Vera Rubin, and Kent Ford. The latter two researchers, both with the Carnegie Institution, are noted for finding some of the "best evidence" for dark matter.

In studies conducted during the mid 1970s, Rubin and Ford plotted the rotational speeds of over sixty spiral galaxies. Their research revealed that matter near the galaxy's outskirts orbits the center just as fast (and sometimes faster) as matter near the nucleus. This went against physicists' prevailing notions about rotating systems. They thought that galaxies, like the solar system, rotated more slowly out at the fringes, where there was less apparent — i.e., bright — matter, and

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rotated more rapidly near the center where most of the matter seemed to be concentrated.

This finding has since been confirmed by other researchers. Moreover, radio studies of neutral hydrogen gas well beyond the optical edges of spiral galaxies also show a flat and sometimes even an upward curve in rotational speed with distance from the center. The inescapable conclusion is that more mass must be present in galaxies than can be seen; astronomers believe about 90 to 95 percent, in fact.

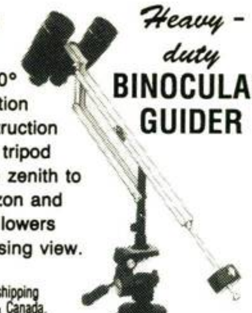
As we learn in chapter five, there also seems to be a mass discrepancy for the universe as well, except that the matter missing from galaxies and galaxy clusters may not be related to that missing from the universe.

The total amount of mass in the universe determines whether or not it will expand forever (an open universe) or one day cease expanding and, perhaps, collapse in on itself (a closed universe). If the universe is closed, space at great distances should be curved. Cosmological tests for curvature — such as measurements of the mass and luminosity of nearby-versus-distant elliptical galaxies and counts of galaxies of various magnitudes in a given direction in the sky — consistently indicate a flat or open universe. So far, no measurements have implied a closed universe.

This goes against what Parker calls a "prejudice" among astronomers for a closed universe. Although there are theoretical reasons to support this more philosophically satisfying concept, the problem is in finding enough mass to close the universe. Could the unseen matter around galaxies be part of this missing mass?

The two problems may be distinct. As Parker points out via a quote from James Peebles, astronomers have measured galaxies and galaxy clusters and *know* that matter is missing, but they can't identify it. In the case of the universe, however, "you measure and you find it's not there. But you want to believe it's there." Hence, solving the dark-matter problem on the galactic scale might not solve the dark-matter problem on the cosmological scale.

Later chapters discuss in detail the candidates for dark matter (black holes, brown dwarfs, neutrinos with mass, exotic particles) and present the problems astronomers have in making them "fill out" the invisible universe. Along the way is a comprehensive assessment of what astronomers know today about galaxy formation (integral to the missing mass problem) and gravitational lenses.



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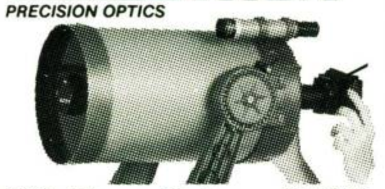

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Chapters thirteen and fourteen delineate the various stages of open and closed universes: star and galaxy death in the far-flung open universe, and what it would be like to approach the singularity of the Big Bang 100 billion years after the closed universe "turns around" and collapses back on itself.

Chapter fifteen, entitled "The Future of Civilization and Life," was the only chapter that seemed out of pitch with the rest of the book. The theme, remember, is invisible matter and the fate of the universe; a chapter on the fate of civilization just seems out of place. Although I agree with Parker that Earth's destiny and the survival of mankind are critical issues, this book may not have been the place for this chapter. I think the continuity would have been better served by dropping chapter fifteen in favor of chapter sixteen, the epilogue, which is the book's rightful summary. Parker should consider writing a separate book with chapter fifteen as the premise.

Supplementing the text are numerous diagrams and color photographs. A brief glossary is provided, as well as a substantial chapter-by-chapter bibliography.

For the reader wrestling with the mind-boggling concept of how something unseen can affect the fate of the universe, *Invisible Matter* is as illuminating as it is convincing. Parker's articulate descriptions of the observations and his explanations of the tell-tale physical effects of dark matter on visible matter give the book a tensile strength and clarity not often found in popular science writing today. *Invisible Matter* should appeal to anyone wanting to learn more about the missing-mass controversy and how it is changing the way we perceive the universe. — *Jeff Kanipe*

CONSTELLATIONS MISSES THE MARK

The Constellations: An Enthusiast's Guide to the Night Sky by Lloyd Motz and Carol Nathanson, (Doubleday, 1988), ISBN 0-385-17600-7, hardcover, 411 pages, $24.95.

"With terrifying screams, the wind lashes angry water into great explosions of froth. Huddled below, the frightened sailors have already hauled in the sails, but this storm's appearance was so sudden that it has washed away most of their provisions."

So begins *The Constellations,* which goes on to tell how the sailors use a bright star and their knowledge of constellations to navigate to safety. This enthralling introduction nicely sets up a

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book about a much-neglected subject, the sky's eighty-eight constellations. However, the book that follows is not that book. Instead, *The Constellations* is a general guide to observing the objects within constellations — a sort of one-volume *Burnham's Celestial Handbook* with few photos and no data tables.

The Constellations appears confused about its audience. A few pages after the sea story, constellations fade into the background as readers get a general discussion of celestial coordinates, stellar parallax, magnitudes, and spectra. Where is the content going? Beginners must feel lost going from myth abruptly into the details of bolometric magnitudes, absorption spectra, and the Morgan-Keenan classification scheme.

The bulk of the book consists of object descriptions arranged by constellation. The constellations are organized by season and grouped into threes or fours, which leads to some pretty awkward chapter titles, such as "Completing the Orion Scene," "Two Damsels and a Herdsman," and "More Animals."

Within each constellation, the authors have done a generally respectable job of relating what each constellation contains. However, they stop short of describing starfields and deep-sky objects as they appear in telescopes. At certain points the authors give brief mythological information or break into sections describing the astrophysical nature of various objects. Although these sections are written well enough at the sentence level, the reader is too often jarred by radically shifting topics at the paragraph level.

The book is also out of date before its time. The coordinates used for discussing objects are for equinox 1950.0 (the standard today is 2000.0), a minor flaw but nonetheless incompatible with current star atlases. The figures given for magnitudes, sizes, and distances of objects are frequently drawn from old sources, which often makes them significantly wrong. This happened despite the fact that *Sky Catalogue 2000.0,* filled with more modern information, is listed in the bibliography.

Practically every other page contains a black-and-white photo of a deep-sky object, a diagram, or a painting of a mythological scene. The star maps, however, are crowded with labels and appear at varied locations throughout the book, making them difficult to find.

I wish *The Constellations* was a better book. But the authors' failure to keep the focus of the text on the constellations and their use of outdated information undermined any potential this book might have had. — *David J. Eicher* ☐

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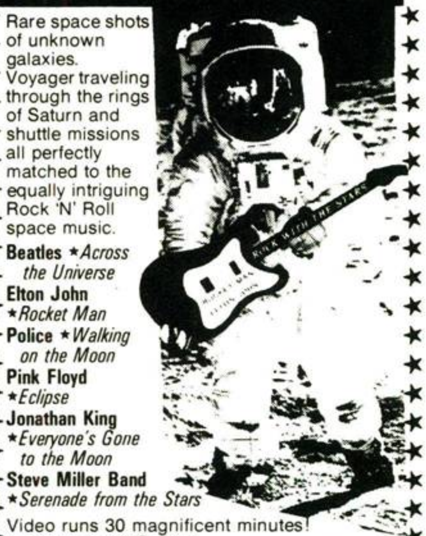

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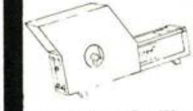

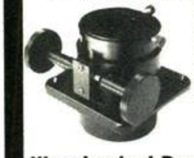

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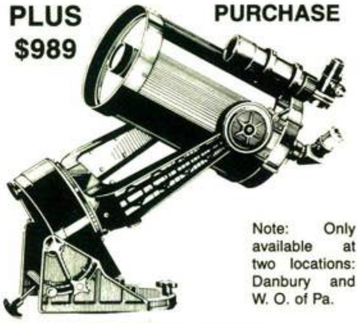

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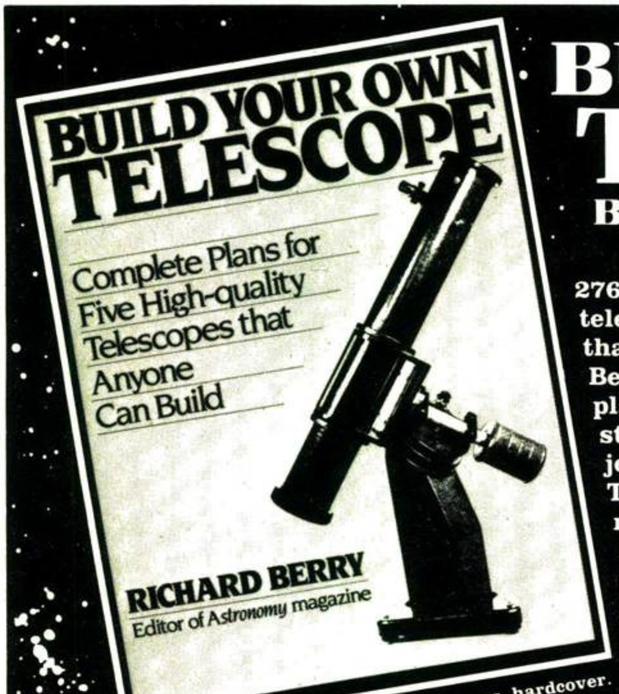

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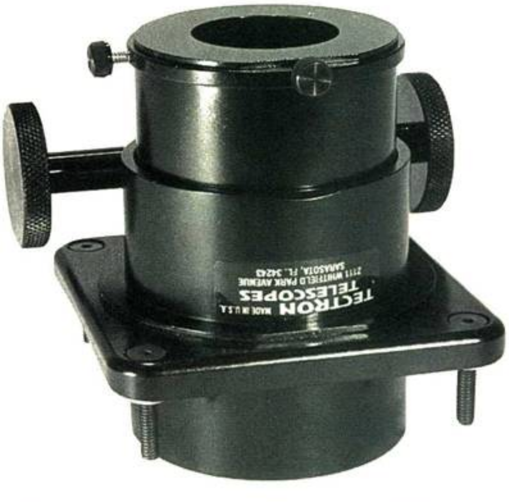
One of the benefits of low-profile focusers is that they can be used with a smaller secondary mirror. Focus planes that are 6 and 7 inches outside the tube require a large secondary mirror for full illumination out to that distance. But when the focus plane is only 2.5 inches outside the tube — as it is with Tectron's photographic focuser — you can use a smaller secondary mirror, thus reducing diffraction effects and obscuration.

Made of machined and black anodized aluminum, the visual focuser is lightweight (14 ounces) but solid enough to hold focus with heavy 2-inch Type II Nagler eyepieces. The visual focuser's minimum height is only 1.6 inches above the tube (the 1.25-inch adaptor supplied with the focuser adds only 0.06-inch to the height). The focusing knobs are large, which makes for easy gripping by gloved hands in winter, and the focuser's moving parts slide on nylon bearings, giving it a smooth, silky motion. If your scope is on a stable mount, you can manually fine-tune the focus without shaking the instrument.

If you want to take astrophotos, the photographic focuser is the system you need. It is identical to the visual focuser except that two nylon thumbscrews allow the entire focuser to slide out of the telescope, leaving the base plate attached to the telescope. You mount your camera (using a standard T-adaptor that you supply) to the camera adaptor that screws into the focuser, which allows you to critically focus your camera. As mentioned, the film-plane height is 2.5 inches, the same as the eyepiece focus plane. This allows you to conveniently move from eyepiece to camera and back again without refocusing.

The machining of both of these focusers is excellent and done to close tolerances. The 1.25-inch adaptor slides in and out effortlessly and includes setscrews for securing eyepieces. The rack-and-pinion gears are solid brass for long-time wear, and each model has an adjustable friction plate. The base plate has an 8-inch radius machined into it, so it fits most mounting surfaces, curved or flat; four mounting screws are provided.

Tectron has recast the standard tall rack-and-pinion focuser into a sound and respectable piece of equipment. The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simple design, smooth performance, high-quality machining, and reasonable price of both the visual and photographic focusers are the best reasons for considering them, if you are either building a telescope or replacing an old focuser. — *Jeff Kanipe*

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If you've ever been frustrated by dew forming on your Telrad sight window, the Dry-Sky shield is a simple device that may help alleviate the problem. Made of lightweight black plastic, the shield simply wraps around the Telrad finder and either attaches permanently, using supplied mounting tape, or temporarily, using a well-placed paper clip (mounting instructions are provided). The surrounding shield deters dew from settling quickly on the exposed angular glass sight. It also protects against dust and fingerprints.

In regions where dew is a constant problem, it is best to add a lining of adhesive-backed black felt to the inside of Dry-Sky. I also did a little experimenting and found that dew can be averted entirely if a flap of black felt is fitted over the front end of the Dry-Sky using a strip of adhesive Velcro along the top of the shield. The flap can be flipped over the opening when the Telrad is not in use, thus preventing dew from settling on the window inside the shield. Not elegant, but it works. — *Jeff Kanipe*

A LITTLE NIGHT MUSIC

Flightpath by John Serrie (Miramar Images, Inc., 200 Second Avenue West, Seattle, WA 98119-4204), chromium oxide tape $9.98 (also available as a CD, $14.98.) plus $2.00 shipping. Available in some record stores. Duration 46:21.

Do new-age music publishers keep sending us their tapes and discs because they found out that many amateur astronomers enjoy listening to music when they observe? Trouble is, not all amateur astronomers enjoy listening to new-age music. Stroll among the telescopes at any star party these days and you're likely to hear all kinds of music —from the Grateful Dead to Hank Williams to J. S. Bach. (For the extremely bent of mind, there's Monty Python.) Taken together, it all amounts to polyphonic mayhem. Thankfully, most keep the sound turned down.

John Serrie's *Flightpath* will suit those who prefer more sedate, introspective observing with music that is innocuous and yet sets the mood for their observing activities. The music is new-age, featuring layered synthesized string ensembles, wafting melodies, and subtle percussion riffs against a background of largely monotonic tones like those heard from a conch shell.

As I listened to *Flightpath,* it struck me that Serrie's music is particularly suitable for deep-sky observing. (Planet observers will have to stick with Gustav Holst!) The palpitating title song would enhance the study of double stars or star clusters, while the following selection, the more sedate "Sky Safari," would set the pace for observers exploring the arms of bright spiral galaxies, like the Andromeda and Whirlpool galaxies. I've decided that "Muroc" — Serrie's tribute to the California airbase that was the site of some of aviation's greatest historical feats — is the soundtrack for the Orion Nebula. The music's incorporeal stream of low tones contrasted with a high, heavenly chorus is an aural analog to the light-and-shadow play evident among the clouds of ionized hydrogen and dark dust. (And you thought all you needed was a larger telescope.)

The fourth selection, "Outreach," with its thrumming bass cadence, is Milky Way cruising music for binoculars and rich-field scopes. "Deep Starship," reverberant and remote, is clearly nebula-hunting music and goes well with the Veil or California nebulae.

Finally, "Glyder" is for vigilant comet hunters sweeping the morning skies for those faint emissaries from the outer solar system. The brightening eastern sky and chittering birdies are a perfect complement to the electronic glissandos and airy tone drones of this piece.

Flightpath, like Serrie's first release, *And the Stars Go With You,* is the perfect celestial mood music for jazzing up those all-too-quiet star parties or backyard observing sessions. — *Jeff Kanipe* ☐

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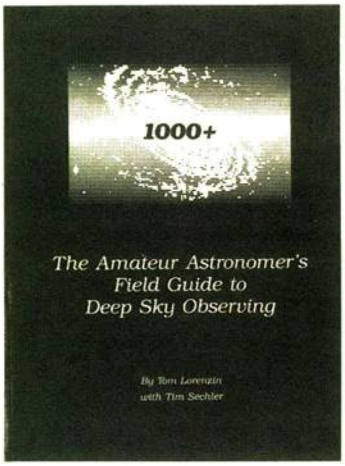

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16th Annual Astronomical Association of Northern California Conference, Lawrence Hall of Science, Berkeley, California. Sponsored by the Astronomical Association of Northern California. Contact: Don Stone, 731 Camino Ricardo, Moraga, CA 94556. Phone: (415) 376-3007.

December 15-22
Winter Solstice Archaeoastronomy Research Course, southeastern Utah. Sponsored by the Four Corners School and Prescott College. Contact: Janet Ross, East Route, Monticello, UT 84535. Phone: (800) 525-4456.

January 9-13
The 1990s: A New Decade for Astronomy, Crystal City, Virginia. Sponsored by the American Astronomical Society. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009

January 25-28
6th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. ☐

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FOR SALE – Meade 8x50 polar illuminated view finder with mounting bracket. Perfect condition. $75 includes shipping. Contact Maurice Schuh, Jr., 1235-50th Avenue North, St. Petersburg, FL 33703.

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WANTED — The Amateur Astronomy Society of Iran is seeking international assistance and a bilateral relation with persons or institutions to increase the general knowledge of astronomy in our country. Contact Babak Sedehi, Amateur Astronomy Society of Iran, P.O. Box 471, Isfahan 81655 Iran.

WANTED — Complete set or individual back issues of *Telescope Making*. Contact Joe Marietta, 512 East Springhill Terrace, Jacksonville, NC 28546. Phone (919) 353-8418.

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Neptune Revealed (page 22)

Now that the flyby is over, you may enjoy rereading ASTRONOMY's features on Triton, the ring arcs, and Neptune's atmosphere. See "Searching for the 'Real' Triton," February 1989; "Running Rings Around Neptune," May 1989; "Approaching Neptune," August 1989; and "Triumph at Neptune," November 1989.

The Legacy of Edwin Hubble (page 38)

Man Discovers the Galaxies by Richard Berendzen, Richard Hart, and Daniel Seeley, (Science History Publications, 1976). Traces mankind's discovery of the Milky Way and the galaxies from the perspective of the expanding universe. Includes chapters on Hubble.

The Red Limit by Timothy Ferris, (Quill, 1983). Excellent summary of Hubble's work and its repercussions.

Realm of the Nebulae by Edwin Hubble (Yale University Press, 1982). Hubble writes about his own work.

Will It Be Clear Tonight? (page 74)

Instant Weather Forecasting by Alan Watts, (Dodd and Mead and Company, 1976). This handy little book helps you predict trends in weather by judging cloud patterns and wind direction. Includes twenty-four cloud photos showing sky conditions.

Split a Star in Two (page 88)

Celestial Objects for Common Telescopes, volume 2, by T. W. Webb, (Dover Publications, 1962). Contains a catalog chock full of interesting, colorful double stars.

Observing Visual Double Stars by Paul Couteau, (Massachusetts Institute of Technology Press, 1982). An excellent technical introduction to the methods used for double star observation. ☐

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COMING IN THE JANUARY 1990 ISSUE OF ASTRONOMY

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An Observer's Guide to 1990 Plan ahead to catch the major observing events of the coming year with this 12-page preview.

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READER EXCHANGE

ANNOUNCEMENT — Free astronomy bulletin board. M-42 is an astronomy/scientific BBS featuring a wide variety of public domain/shareware software, friendly users, and discussion on astronomy and scientific topics. Phone (314) 997-5157.

WANTED — Mirrors or lenses that are gathering dust. Need optics to build a telescope. Contact The Street People Astronomers, P.O. Box 1619, Everett, WA 98206.

FOR SALE — Twenty-six issue of *Star & Sky* magazine from January 1979-February 1981. $25. Over forty issues of ASTRONOMY. 1985-1989. $50. Contact Pat Walker, 8009 NW 12th Avenue, Vancouver, WA 98665. Phone (206) 573-8063.

FOR SALE — Enhanced Super-Polaris equatorial mount. Tripod legs adjust to 55″. Extras included. Send SASE for photos. $295. Walnut telescope case accented in maple and burl. Neoprene sealed 48x12x9 shell recently handcrafted for 5″ Starfire. Ninety percent complete and visually stunning. $49. Contact Bob Myler, 1751 Grafton Drive, St. Louis, MO 63136. Phone (314) 521-6476 (evenings).

WANTED — ASTRONOMY. January 1982 and February 1982. Needed to fill collection. Mint condition only. Will pay more than cover price. Contact Dan Cothern, 209 South Pine Street, Pana, IL 62557.

WANTED — 13.1″ Odyssey 1. Old blue design. Contact Dave Pearson, 503 17th Street, Huntington Beach, CA 92648. Phone (714) 969-0342.

FOR SALE — Meade DS 16″ f/4.5 Newtonian. Many improvements, 1/20-wave optics, equipped with most accessories, tube rotation rings, Mylar solar filter, and much more. $2,000. Can deliver in Florida. Contact Walter Swentzell, 131 Queen Catherina Court, Fort Pierce, FL 34949. Phone (407) 465-4454.

FOR SALE — Bausch & Lomb heavy-duty German equatorial mount. Includes quartz drive with corrector, built-in polar axis finder scope, setting circles, and adjustable tripod. $350 plus shipping. Contact J. Valdes, 10468 Boynton Place Circle, Boynton Beach, FL 33437. Phone (407) 736-9029.

WANTED — Fifteen-year-old amateur would like to correspond with other young amateur astronomers. Contact Claire Ferguson-Smith, 127A Moreing Road, Attodale, Western Australia 6156.

ANNOUNCEMENT — The Mars Astronomy Club meets the second Thursday of each month at 7:30 p.m. in the Museum of Science and Industry, Tampa, Florida. Contact Emilio Toro, 2401 Bayshore Boulevard #1404, Tampa, FL 33629. Phone (813) 253-3490.

FOR SALE — New, unused books. *Uranometria 2000* and *Burnham's Celestial Handbook* (full set, paperback). $25 each. *Telescope Optics*. $20. *Observing and Photographing the Solar System*. $14. Wanted: 1.25″ eyepiece turret for refractor and *Amateur Telescope Making*, book one. Contact Shawn Mulcahey, 1780 Flores, Thousand Oaks, CA 91362.

FOR SALE — ASTRONOMY. August 1973-present. Includes eleven library cases. Excellent condition. Will sell only as a set. $45 plus freight. Contact Vince Thaner, 52 Central Avenue, West Keansburg, N.J. 07734. Phone (201) 787-5506.

FOR SALE — Celestron C-14 with wedge, tripod, and accessories. $5,000. Meade 10″ 2120/LX3. $1,400. Buyer pays shipping. Contact John J. Maikner, 201 Washington Court, Telford, PA 18969. Phone (215) 723-5342.

WANTED — Members to join the Oaktree Astronomy Club, a postal astronomy club that offers helpful, friendly advice. Membership is 8.50 British pounds per annum. Contact Nigel Dickerson, Membership Secretary, 6C Fern Hill, Dersingham, Kings Lynn, Norfolk, England PE31 6HT.

WANTED — Thirteen-year-old amateur astronomer wishes to correspond worldwide with others of similar age. Will reply to all letters. Will exchange photos and information. Contact April Grisetti, Route 1 Box 233, Boones Mill, VA 14065.

WANTED — *How to Build a Dobsonian* booklet. Contact Michael Tshulos, 4828 Country Club Road, Binghamton, NY 13930.

FOR SALE — Astrocan 2001 rich-field telescope, 28mm and 15mm eyepieces, image erector, tote bag, and two instruction booklets. $250. Must pick up. Contact Sharon Jordan, 9849 Guisante Terrace, San Diego, CA 92124. Phone (619) 278-1157.

FOR SALE — Rare astronomy books such as Neisen's *Moon*. Send for list. Contact D. R. Biswell, 3 Keith Avenue, Sutton at Hone, Dartford, Kent, England, DA4 9HH.

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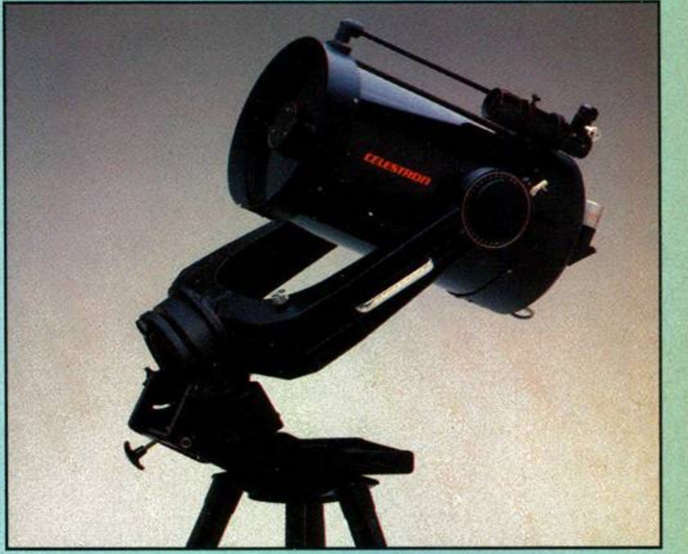

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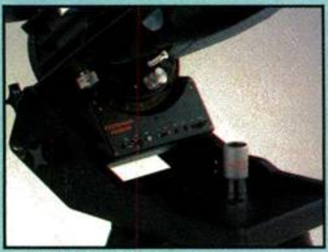

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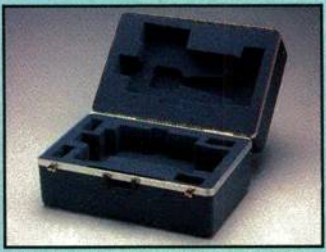

Ultima® 11: Deluxe foam fitted carrying case.

CASTINGS Completely new castings including among others, the rear and front cells and fork tines (twice as large as competitive units). The rugged castings complement the Ultima's large aperture and make viewing and astrophotography a delight.

CARRY HANDLES Setting up and moving the telescope is easy with the carrying handles on both fork tines and the rear cell.

DRIVE SYSTEM The Ultima® 11 utilizes the drive system base from the successful Ultima® 8. The totally cordless quartz-locked electronic drive system has rechargeable heavy duty industrial grade sealed lead acid batteries (good for 500 charges from AC or DC). No excess wires, cords, etc. Also included is the Byers worm gear drive system (the most accurate of commercial Schmidt-Cassegrain's with its 7.54″ diameter and 359-tooth gear (30% larger and twice as many teeth as competitive units). The polar axis ball bearings are precision loaded and 4″ diameter. The polar shaft is integrally cast into the base and is much larger and more stable than other units on the market.

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FOOTPADS Anti-vibration footpads for the tripod are standard adding even greater stability.

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